Plant Breeding Plots
New Jersey Agricultural Experiment Station

LIPPINCOTT'S
FARM LIFE TEXT SERIES
EDITED BY
KARY C. DAVIS, PH.D. (CORNELL)

APPLIED ECONOMIC BOTANY

LIPPINCOTT'S
FARM MANUALS

Edited by
K. C. DAVIS, Ph.D.
KNAPP SCHOOL OF COUNTRY LIFE, NASHVILLE, TENN.

PRODUCTIVE SWINE HUSBANDRY 1915
By GEORGE E. DAY, B.S.A.

PRODUCTIVE POULTRY HUSBANDRY 1919
By HARRY R. LEWIS, B.S.

PRODUCTIVE HORSE HUSBANDRY 1916
By CARL W. GAY, D.V.M., B.S.A.

PRODUCTIVE ORCHARDING 1917
By FRED C. SEARS, M.S.

PRODUCTIVE VEGETABLE GROWING 1918
By JOHN W. LLOYD, M.S.A.

PRODUCTIVE FEEDING of FARM ANIMALS 1916
By F. W. WOLL, Ph.D.

COMMON DISEASES OF FARM ANIMALS 1919
By R. A. CRAIG, D.V.M.

PRODUCTIVE FARM CROPS 1918
By E. G. MONTGOMERY, M.A.

PRODUCTIVE BEE KEEPING 1918
By FRANK C. PELLETT

PRODUCTIVE DAIRYING 1919
By R. M. WASHBURN, M.S.A.

INJURIOUS INSECTS AND USEFUL BIRDS 1918
By F. L. WASHBURN, M.A.

PRODUCTIVE SHEEP HUSBANDRY 1918
By WALTER C. COFFEY, M.S.

SOIL PHYSICS AND MANAGEMENT 1919
By J. G. MOSIER, B.S., A. F. GUSTAFSON, M.S.

APPLIED ECONOMIC BOTANY 1919
By MELVILLE T. COOK, Ph.D.

LABORATORY MANUAL AND NOTEBOOK
ON THE FOLLOWING SUBJECTS

SOILS, By J. F. EASTMAN and K. C. DAVIS 1915
POULTRY, By H. R. LEWIS 1918
DAIRYING, By E. L. ANTHONY 1917
FEEDING, By F. W. WOLL 1917
FARM CROPS, By F. W. LATHROP

FARM LIFE TEXT SERIES

EDITED BY K. C. DAVIS, PH.D. (CORNELL)

APPLIED ECONOMIC BOTANY

BASED UPON ACTUAL AGRICULTURAL AND GARDENING PROJECTS

BY

MELVILLE THURSTON COOK, PH.D.
RUTGERS COLLEGE, NEW BRUNSWICK, N. J.

142 ILLUSTRATIONS

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

Electrotyped and printed by J. B. Lippincott Company
The Washington Square Press, Philadelphia, U. S. A.

PREFACE

THERE are already so many text-books on botany that the author has long hesitated to present another to the educational public. The study of botany has developed very rapidly in the past quarter of a century and as a result we have a great variety of text-books representing an almost equally great variety of methods of presenting the subject. Yet, we meet with a continuous series of complaints against the poorly adapted secondary text-books for teaching in secondary schools, technical schools and colleges. The teacher in the secondary school says that text-books are written by college professors who do not understand the problems involved in secondary education; the teacher in the technical school complains because the students from the secondary schools cannot correlate the botany with related subjects; the college professors complain because of the mechanical methods used in the secondary schools which discourage rather than encourage further study of the subject by those who enter college.

Having served for a time as a high-school teacher, the author has some realization of the difficulties of the secondary schools. As a college professor he has some appreciation of the keen disappointment felt by those who conduct the Freshman entrance examinations, and who try to teach botany to the college students that come to college with ideas of botany obtained from their training in the secondary schools. By experience, he has learned that the results of the entrance examinations are fully as unsatisfactory when the questions are prepared by the high-school teachers as when prepared by himself.

The placing of the responsibility for this condition is a

problem not easily solved. But the writer is inclined to believe that the secondary school is trying to do too much, trying to do work beyond the pupils, trying to do work that should be left for the college. We give the pupils compound microscopes, which is much like giving them a complete set of surveying instruments for use in the study of elementary arithmetic. We try to teach facts when we should teach fundamental principles, close observation and accuracy. We try to teach scientific names when we should teach simple methods of experimental work.

In this little work the author has aimed at three things, *viz.:* (1) A brief statement of the recognized facts and principles concerning plants and plant growth usually given in text-books for secondary schools. (2) A list of simple exercises and suggestions for observations which the pupil can conduct without great difficulty and which will demonstrate many of the statements given in the book. (3) A list of questions which are intended to be suggestive to the pupils and to encourage further studies.

The title, "Applied Economic Botany," implies first, that it is intended as a guide to experimental work in the study of plants, such as should be carried on in any high school, and second, that it is intended as a preliminary work to the agricultural studies which are now recognized in many high schools.

The author has endeavored to make the work so flexible that it may be used in schools regardless of the amount of time devoted to the subject, the available laboratory space and equipment. The author has also been mindful of the fact that the course in botany in the secondary school should meet the needs of very different classes of pupils—those who study it as one of the requirements of the curriculum and to whom it must be primarily a cultural subject, those who study it as a preparation to agriculture and horticulture, and those who may use it

to fulfill one of the college entrance requirements. The same course can and should serve all of these purposes in the same manner that the courses in mathematics and English literature serve those who go direct from the secondary schools into the trades, or business houses, or professions, or to college.

The manuscript has been submitted to both high-school teachers and college professors for criticisms and suggestions and many changes have been made in an effort to meet the requirements of both classes of teachers, although the general plan of the work has not been changed.

Many of the illustrations in this book are purely diagrammatic and are intended as guides and not completed work to be copied by the pupil; many others are from drawings made by the author's students and are such as can be readily made by most high-school pupils.

A text-book in botany is a guide, and it is neither necessary nor desirable that the class should follow it in all details. The teacher should select such exercises in this or other books as may suit the purpose and should make such variations and additions as may be desirable. Supplementary reading along the lines of plant geography, and economic botany, observations in field, forest and stream, and home studies in the growing of plants should be encouraged. The success or failure of the course in botany is more dependent on the teacher than on the books, laboratories and equipment. *A good teacher is more necessary than books, laboratories and equipment.* The acquirement of industry, enthusiasm, methods of work, self-reliance, close observation and accuracy on the part of the pupils are much more desirable than much of the so-called knowledge that consists of disconnected or questionable facts.

MEL. T. COOK.

RUTGERS COLLEGE,
NEW BRUNSWICK, N. J.

CONTENTS

INTRODUCTION

BOTANY is a science of the very greatest importance but one which is frequently misunderstood and neglected in our educational system. To many people, it means the learning of scientific names of plants, but this is an incorrect idea. Botany is neither the study of flowers nor the learning of scientific names. *Botany is the study of plants and plant life.* It is of great importance because plant life is absolutely necessary for the existence of all animal life, including mankind. We are dependent either directly or indirectly upon the plants for food, clothing, building materials, fuel and many other necessaries. We use plants, or animals which have fed on plants, for food. Every article of food on the table, except the salt and water, is derived from plants or from animals which are dependent on plants for food. We use cotton and linen, and many other vegetable fibres, for clothing and many other purposes; and we also use wool and silk which are derived from animals that have fed on plants. We use wood for building purposes, for making furniture and parts of tools and implements, and for the making of paper pulp. We use wood and coal and oil, which are derived from plants, for fuel. And finally, we go to the plants for about 90 per cent of the drugs to relieve our aches and pains and restore us to health.

When we once realize our absolute dependence on plant life, we also begin to think something about the number of industries that are dependent on plants. The farmers, the horticulturists, the gardeners, the florists and the foresters are not the only people who are dependent on plants for a livelihood. Practically all manufacturing industries are dependent on plants in some form; for fuel if for nothing else. Even the electric establishments must use fuel to run the machinery for the generation of

electricity. When we think of these things we wonder why it is that man has not given more attention to this primary source of life, health, wealth and happiness; why he has not given more attention to increasing it. The answer lies in the fact that nature is good to us; nature has supplied man with the necessaries and more, and man has been satisfied. But with the increasing population it will become more and more necessary for man to study plants and plant life and to learn the secrets of nature which will enable him to increase the production of valuable plants.

Plants have influenced the migration of man. In the account of his journeys of discovery and exploration he has always given much attention to the character of the plant life. And most of the permanent settlements of importance have depended on the character of the plant life and the possibilities for agriculture. Big factories may have been located where the water power was good, but they must also be accessible to the raw materials to be used; or they may have been located near the great beds of coal, oil or natural gas and in that case they were dependent upon the plant products of past ages. However, the great migrations of the world have always been along the lines of great plant growths, and the early settlements in America and the rapid progress of the American people, with which you are familiar, are ample proofs of these statements.

But this is not all; the great joy of life is in life itself. To fully enjoy the life within us we must take pleasure in the life around us. The joy of the country, of the forests and plains, the mountains and valleys, of the parks and gardens, is not only in their beauty but in the appreciation of the value of the plant life which makes them beautiful.

Botany cannot be studied like most subjects; it does not consist in committing facts. It cannot be learned from books, for there is no botany in books. Books contain a *few* plans and methods for study; a *few* records of observations and studies

already made; a *few* facts already learned. The plans and studies may be changed to-morrow; the records of observations and studies will be increased; and many of the supposed facts may prove to be errors and be supplanted by other statements.

No, we must not study books; we can use the books as guides, but we must study the plants themselves. Louis Agassiz said, "*Study Nature, not Books*"; and in studying botany, we should study the nature of plants and not the nature of books. In this brief work we can give but very few of the best known and simplest plans and methods for study and a very brief statement of facts. Many volumes have been written on botanical subjects, and botany is now recognized as well worthy of the time and attention of the most learned men and women of our age. When we compare the knowledge that we have of plant life with the many problems of plant life yet unsolved we realize that we know but very little of the subject. Plant life lends itself so readily to observation and study that the pupils of a beginning class may quickly learn many things not recorded in your text-book.

The first question that you ask when you see a strange plant is, what is its name? We learn to know plants by their common names, but the common names used in one part of the country may be entirely different from those used in another part, and, of course, the common names must be different in different languages. Therefore, it is necessary for the botanists to use scientific names (mostly Latin) which will be the same in all parts of the world and in all civilized languages. But these names must also show something else, they must show the relationship of plants. This working out of the relationship and classifications of plants is known as *systematic botany* or *taxonomy*. This subject will be considered again in Chapter V.

But this is only one phase of botany. We should know something of the structure of plants, of the parts of which they are composed. This study involves the comparison of the

different parts of the plant and the comparison of the parts of one plant with those of another kind. It is known as *morphology* and will be the basis of much of our study.

But there is still a third phase of botany, the studies of the activities of plants, their methods of securing food, their growth, their reproduction and their behavior in general. This is known as plant *physiology* and will also be the basis of much of our study. Let us always remember that plants are living things just as much as animals are living things and should be studied as such.

Therefore, we may say that there are three great divisions of botany, TAXONOMY, MORPHOLOGY and PHYSIOLOGY. However, we have made many other divisions of the subject which are more or less artificial, but which are very convenient for study. The most important are: *Agricultural botany, horticultural botany, floriculture, forestry, plant pathology, pharmaceutical botany, plant geography* and many other divisions to please the individual workers. But they must all depend on some one, two or all of the three great divisions. We will give some attention to them later.

There is much to be gained in the study of plants that is more far-reaching than the subject of botany. After all, our education consists more in training than in facts learned. We cannot, in the short time allowed to the subject, expect to learn much about many thousands of plants, growing under the varied conditions found in the different parts of the world, but we can learn certain principles of plant growth. We can also learn to be close observers of both the plant and animal life around us and we can also learn to be accurate in our observations, in our experiments and in making records. If we learn *close observation* and *accuracy* in our work we will have gained a training well worth all the time devoted to this subject; a training which will be helpful in any future trade, business or profession that we may enter.

EQUIPMENT AND METHODS

The necessary equipment for a course in botany will vary with the time devoted to the subject and the available laboratory space. If you do not have a laboratory, many interesting studies can be made and experiments conducted in the ordinary school-room.

The simplest possible equipment is a good pocket knife, a small hand lens, a note-book suitable for drawings and records and a reasonably hard lead pencil.

To this equipment may be added flower pots, tin cans, bottles, glass jars, glass and rubber tubing, boxes, seeds, bulbs, fruits, vegetables, living plants, sands and soils. The amount and variety of supplies of this kind will depend on the available space for the work. Practically all of these supplies can be secured from the local merchants or collected in the vicinity.

The laboratory should be well lighted and properly heated both day and night, and should be supplied with tables, shelves, water and a dark room.

The library should contain as good a supply of text-books on general botanical and agricultural subjects as is possible to secure. *The daily work should always be supplemented with readings on botanical subjects.* The study of botany may be correlated with many other subjects, especially chemistry, physics, geology, soils, geography, agriculture, horticulture, gardening, agronomy, meteorology, and history.

The indoor studies should always be supplemented by outdoor studies. Walks in the parks or country after school hours, or on a Saturday, will prove exceedingly advantageous. The growing of plants at home, the determining of the number of different kinds of trees in a piece of woodland, along a street or in a park are usually both interesting and helpful.

The number of dissecting and compound microscopes will depend on the number of pupils and the time allotted to the subject. Secondary schools have but very little use for microscopes and can get along very nicely without them. They should not be used except for the demonstration of a few points on the structure of the plants. It is far better that the pupil have a good understanding of a few fundamental principles of plant growth than a poor understanding of plant structure.

There is no hard and fast line between botany and agriculture and horticulture, and in the agricultural high schools it may be found desirable to merge these subjects into a continuous course on plant studies, but neither the teacher nor the pupil should ever lose sight of the fundamental principles of plant growth. Study plants and plant growth first and agriculture and horticulture will follow in due course.

The sciences are the most variable subjects taught in our schools; new discoveries cause continuous change of views and methods and present new lines of thought. Although botany is in some respects the oldest of the sciences the fact that its greatest developing has been within the last quarter of a century makes it the youngest. These facts explain the great diversity of opinion as to the importance of the subject, the time devoted to it, and the amount and character of equipment.

The author fully appreciates that no teacher can dictate methods of teaching botany to another teacher, but suggestions may be given which are well worth consideration. The first suggestion that the author makes is that the pupils should recognize the importance of the subject. Botany should appeal to the every-day life of the students; the pupils learn to read, that they may read not the one exercise at the set period, but that reading may be used by them for pleasure and business in every-day life; they learn arithmetic not for the class period but that it may serve them in their vocational work; and they should

study botany with the idea that it is to be of future use, that it may help to earn a livelihood, that it may contribute to the joy of living.

Botany should be taught differently from most subjects. History may be more or less complete, truthful records and deductions; mathematics may be exact; but natural science implies doubt, and the pupils should approach the experiment with doubt and with the determination to secure an *honest* result. Of course, the pupil cannot be expected to test every statement in the literature, most of these experiments must be left for another and more advanced worker; but doubt is one of the solid foundation stones of scientific work. No one will ever fully appreciate or enjoy any science who does not approach the subject armed with an interrogation point.

The order of the subjects and experiments will depend on the pleasure and judgment of the teacher. It is not always necessary to follow the outline given in this or any other book. Begin with any topic to suit your own ideas. Most teachers will find it desirable to work from the known to the unknown, but the problematical side should be kept clearly in view. The experiments should be prepared with the greatest possible care and accuracy; and originality in apparatus and method should be encouraged. The interpretations and conclusions drawn by the students should be carefully guarded by the teacher. As much attention should be given to the control or check as to the experiment itself. The records should be full and complete and both drawings and records should be accurate and neat.

Mechanical methods, the rock on which nature study was wrecked, should be avoided. All work should have an objective. Devise or select exercises from other books, use other materials than those suggested, or any and all other possible methods to prevent "rule of thumb" work.

One of the oldest devices in teaching botany was the making

of collections under the belief that the pupils would thus learn to know plants. It is not necessary to explain the shortcomings of this method to any who have tried it. We all appreciate the importance of having pupils know the common plants, but a knowledge of the laws of plant growth and of the relations of plant groups is of much greater importance than scientific names. Collections should be made in the same manner as experiments, *i.e.*, with an objective. Collections illustrating certain groups of plants or a certain number of groups, or of the plants of a locality, or of the economic plants, or of the plants used in certain industries may often be made with great profit.

Additional work for the bright and willing students is to be encouraged. Pupils with a love for the work will do much more than the requirements and are the real joy of the teacher.

PART I

PLANT LIFE

APPLIED ECONOMIC BOTANY

CHAPTER I

SEEDS AND SEEDLINGS

THE seeds of a plant are such familiar objects that most of us fail to appreciate their very great importance. Of course, we know in a general way that a new plant may come from a seed and that the seeds of this new plant will produce other plants. We also know that the seeds of many plants are used as food by man and beast. However, few people have any very clear ideas of the structural or chemical characters which make the seeds of some plants valuable for food while the seeds of others are useless for this purpose. Neither do they have a very clear conception of the parts of the seed which produce the parts of the young plant and the conditions necessary for their development. Let us examine and compare a few seeds and try a few experiments with the seeds of different plants to determine these points.

Parts of a Seed.—The seed is a young plant and its food supply. It is in a dormant or resting state and is waiting for the necessary conditions before growing into the form generally recognized as a living plant. The most important parts of a seed are, (*a*) a miniature plant known as the embryo and which under certain conditions will develop into a full-grown plant; (*b*) an ample supply of exceptionally nutritious food for the nourishment of the new plant or seedling until it becomes self-supporting; and (*c*) the necessary protective covering (Figs. 1, 2 and 3).

The little plant within the seed is complete in itself. It pos-

sesses all the organs of a mature plant; *root, stem* and *leaf*. All the other parts of a plant with which we are familiar, such as flowers and fruits, are modifications of these primary organs. The food within the seed is especially well suited for nourishing the young plant during the early stages of its development and under favorable conditions of warmth and moisture is readily utilized for this purpose. The highly nutritious character of

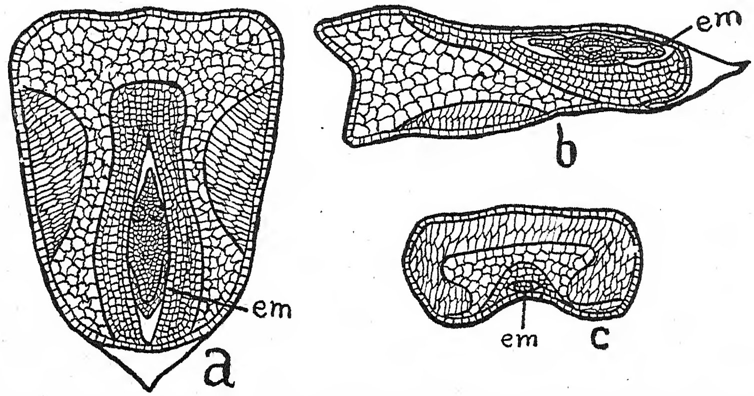


FIG. 1.—a, diagrammatic under-side view of a grain of corn showing the embryo (em) and the layers of food; b, longitudinal section of corn showing same parts; c, cross-section of grain of corn showing the same parts.

this stored food makes many seeds, such as corn, wheat, oats, beans and peas especially useful as food for man and animals. (Chapter IX.) The outside coverings of different kinds of seeds are extremely variable in character and have many modifications, some of which aid in their distribution. These points will be discussed later. (Chapter VII.)

Two Classes of Seeds.—Seeds are extremely variable in size, shape and color, but they can be readily grouped into two main classes, monocotyledons and dicotyledons, dependent on whether they possess one or two cotyledons or primary leaves. These cotyledons are easily recognized in most large seeds, such

as the bean, which is made up almost entirely of two large cotyledons. These two classes include all the true flowering plants which are frequently referred to as monocots and dicots, or mono and dicotyledonous plants. Our common Indian corn is a good example of the first and the common bean of the second of these groups.

Storage of Food.—There are two general types of storage of food in seeds. In some seeds the entire food supply is to

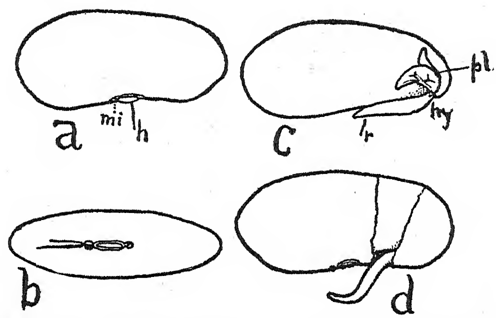


Fig. 2.—Seed of lima bean; a, b, showing micropyle (mi) and hilum (h); c, with seed coat and one cotyledon removed showing root hypocotyl (hy) and plumule (pl); d, germination.

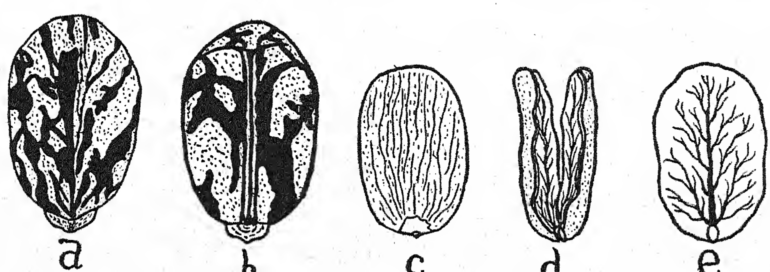


Fig. 3.—Seed of castor oil plant; a and b, upper and lower surfaces; c, after removal of the seed coat; d, e, cotyledon showing leaf characters.

be found in the cotyledons, as in the case of the bean (Fig. 2), while in others the food is found in the cells which immediately surround the little embryo plant, as in the corn and the so-called castor bean. (Figs. 1 and 3.) In these latter cases the cotyledons frequently serve as organs through which the stored food

passes to the young growing plant. In some seeds, of which corn is a good example, the only apparent function of the cotyledon is for absorption of the stored food, but in the castor bean the cotyledons serve first for absorption and later as foliage. In some seeds the cotyledons serve for storage only, but in others they serve for storage and as the first leaves.

The corn, bean and castor bean are most excellent types for study. They are easily secured, large and easily handled, and possess all the characters commonly found in seeds. They illustrate all the preceding points concerning cotyledons and food supply.

A grain of corn is flat, almost triangular in shape and has a depression or groove on one side. Lying beneath this groove is the little embryo plant with its root turned towards the point of the grain, and the stem and cotyledon towards the large end. The embryo plant is almost surrounded by the tip or endosperm starch. The remainder of the grain is made up primarily of starch, which is covered with a thin layer of gluten and a thin membranous, horny coat. The corn is not a simple seed in the same sense that the bean is a simple seed. You will recall that the bean seed is removed from the pod. But the grain of corn is not taken from a pod. In fact, the thin membranous horny coat just referred to is the pod which adheres to the seed covering or seed coats. Therefore, the grain of corn, as we shall learn later, is not a simple seed, but a fruit. The grain of corn consists of the embryo plant, surrounded by the stored food and enclosed in a thin membranous covering consisting of the united seed coat and pod. The grains of wheat, oats and other grasses possess similar characters. (Fig. 1.) The embryo consists of a single cotyledon (or primary leaf), a short stem and a short root.

The seed of the bean is very different from the grain of corn. The two large fleshy parts are the cotyledons and since there are two of them it is a dicotyledonous seed. They are the

primary leaves and they also contain the food supply. They are united by a very short embryonic stem, known as the *hypocotyl* (*i.e.,* the part below the cotyledons). Of course, this hypocotyl is very short, but from one end arises the primary root, which is known as the *radicle,* while at the opposite end we find the minute bud known as the *epicotyl* (*i.e.,* the part above the cotyledons). These parts are covered by the seed coats which show certain markings. The scar, marking the point of attachment, is known as the *hilum.* On one side of this hilum we find a slightly raised ridge known as the *raphe* and on the other side we find a minute opening known as the *micropyle.* (Fig. 2.)

The seed of the castor plant is dicotyledonous like the bean, but the food is stored as an endosperm around the embryo, as in the case of the corn, instead of in the cotyledons, as in the bean. The arrangement of the various parts of the embryo is the same as in the bean, but the cotyledons are very thin and show their leaf-like character very distinctly. The entire embryo is surrounded by the food supply which is enclosed within the seed coats. At the tip of the seed there is a mass of spongy material, covering the hilum. It is called the *caruncle* and will be discussed later. (Page 12.) The embryos of monocotyledonous seeds are usually smaller than those in dicotyledonous seeds. The food supply in the former is always found surrounding the embryo, while in the latter it may be either around the embryo or in the enlarged cotyledons. Embryos in which the food is in the cotyledons are usually more advanced in their development before ripening than those in which the food surrounds the embryo. In the former the embryo has absorbed its food supply before ripening, while in the latter it must be absorbed during germination. (Fig. 3.)

Conditions for Sprouting.—When the seeds of most plants are ripe they can be stored in a dry place and kept for a long time, and then used for planting. But of course, the seeds of

the uncultivated or wild plants are not stored, they remain weeks or months exposed to the weather and when the conditions are favorable they germinate readily and grow. The seeds of some plants will grow immediately, but the seeds of most plants will not grow until they have passed through a period of rest. The seeds of many plants will not sprout unless subjected to the action of frost. This is especially true of many nuts and the seeds of some other forest trees. The seeds of some water plants remain in the water for long periods of time before sprouting. When the seeds of a plant have undergone their proper period of rest and have been brought either by nature or by man into favorable conditions of *warmth*, and *moisture* and *air* they show signs of life and the embryo plant resumes its growth; that is, it increases in size and is very soon readily recognized as a young plant. During the early stages of its growth, the young plant lives on the food which is stored in the seed. By the time this supply of food is exhausted the young plant is sufficiently well developed and established to manufacture its own food from raw materials that are secured from the soil and air. The three most essential factors for the sprouting of seeds are warmth, moisture and oxygen of the air.

Warmth.—The most favorable temperature for most garden and field seeds ranges from 85 to 95 degrees, Fahrenheit, but it is not the same for all plants. Some seeds sprout much earlier in the season than others, while some weeds sprout in the summer or fall and pass the winter as growing plants instead of being stored until spring. The farmer has long ago learned the best time for his various crops. Winter wheat, clover and grasses are sown in the fall; corn, oats and many other seeds in the spring.

We all know that seeds cannot sprout without water, although a very small amount is necessary for the sprouting of some seeds. The dry seeds of some plants may be kept for

long periods of time, but when placed in moist surroundings they absorb water rapidly and in great abundance, swell and sprout very quickly.

Oxygen from the air is also of very great importance in the sprouting of seeds. Even when seeds are supplied with the proper warmth and the proper amount of water but deprived of oxygen they will not grow.

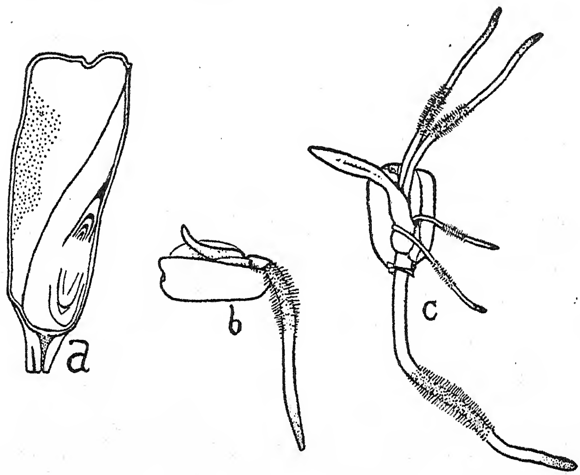


FIG. 4.—a, Longitudinal section of corn seed showing the embryo; b and c, the germinating seed showing the emergence of the root and plumule, the formation of rootlets and root-hair.

Moisture.—However, it is possible for the seeds of some plants to have too much water, which will affect the temperature and interfere with the plant securing the necessary oxygen. In fact, the little embryo plant may be smothered or drowned in very much the same manner as an animal may be killed when submerged in water, but of course it requires more time. Every farmer knows that land for certain crops must be well drained and that too much rainfall in the spring interferes with proper germination, causes grain to rot in the field, and causes those plants that survive to be yellow and weak.

Sprouting Process.—When the seed sprouts the root and stem of the embryo plant elongate, the one growing downward and the other upward; in some seeds the cotyledons remain underground as in the case of the corn and the pea (Figs. 4 and 6), while in other young plants the cotyledons are carried above ground as in the case of the squash and the bean. (Figs. 7 and 8.) It is very important that seeds should not be planted too

Fig. 5. Fig. 6.

Fig. 5.—Bean seedling showing cotyledons and first leaves.
Fig. 6.—Pea seedling. The cotyledons remain below the ground.

deep, but this is especially important in the case of those seeds which lift the cotyledons above the ground. The raising of the cotyledons above the ground is due to the elongation of the stem, and deep planting requires unnecessary growth and tends to the production of a weak plant.

The cotyledons are the first leaves of the young plant and when raised above ground they perform the duties of foliage (Figs. 5, 7 and 8), which will be described later. (Page 11). We have already learned that they may also serve as storage

for food (Figs. 4–8) for the young plant; but they may also have a third function, that of absorption, as illustrated by the germinating corn. (Fig. 4.) In the corn the single cotyledon has been so modified that it serves as a special organ (known as the *scutellum*) through which the food passes from the endosperm of the grain to the embryo. The pea (Fig. 6) and numerous other seeds never raise their food-laden cotyledons above ground, but draw the nourishment directly from them, or through them from the surrounding parts of the seed. In the bean, squash and related plants, the cotyledons serve for storage and also as first leaves for a short time. The cotyledons of the squash (Fig. 7) persist for a much longer time than those of the bean (Figs. 5 and 8) and show their leaf-like character much better. The cotyledons of the castor bean (Fig. 3) serve first, for the absorption of the stored food and, later, as the first leaves. It is very evident that in most plants the leaf characters of the cotyledons vary in proportion as they serve for foliage or for storage. However, it should be remembered that their leaf characteristics vary somewhat from those of the leaves which are formed later.

The very rapid sprouting of seeds is partly due to certain peculiar substances known as enzymes or ferments. These substances are usually produced inside the cells and serve to digest or make soluble or otherwise modify the food which is stored within the seeds, thus making it available for the young plant. Probably the most important of these ferments is known as diastase, an enzyme which changes the starch into sugar in very much the same manner as the ptyalin of the saliva in our own mouths changes starch into sugar. The starch is only slightly soluble in water, but the sugar is readily soluble and therefore becomes an important factor in plant growth.

By the time the supply of stored food is exhausted the young plant has a fairly well developed root, stem and leaf system

enabling it to carry on an independent existence. We will study the root, stem and leaf in the succeeding chapters.

The seeds of some plants retain their power to germinate much longer than those of others. The harvesting of seeds before they are fully ripened is one of the most common causes of loss of vitality, but there may be other factors which tend to injure seeds. These facts make it very important that seeds should be tested and their power of germination determined before planting. (Chapter XVI.)

Germination means the growth or enlargement of the young embryo of the mature seed. We have learned that this occurs under the proper conditions of moisture, temperature and air. The young plant may be considered a seedling until it has used the supply of stored food, and thus becomes an independent plant, drawing its food from water, soil and air.

Since we have three types of seeds it is very probable that we will find three or more types of germination. If we examine the seed of the bean again we will find a very minute opening near the hilum. It is the *micropyle* (Fig. 2 *a* and *b*) through which the water passes very readily. If the micropyle is closed by wax the absorption of water will be much slower. The embryo gradually enlarges and the first evidence of growth that we see is the elongation of the *radicle,* which breaks through the seed coat near the *hilum* and turns downward. The continued enlargement of the cotyledons and plumule forces the seed coats off and the rapid elongation of that part of the stem below the cotyledons carries them above the surface of the soil. This elongated stem is not straight at first, but gradually appears above the soil in advance of the cotyledons as a loop which later becomes erect. (Figs. 7 and 8.)

The seed of the castor plant (sometimes improperly called castor bean) has a small mass of spongy substance (caruncle) (Fig. 3 *a* and *b*) covering the hilum through which the water

is absorbed and passed on to the other parts of the seed. The taking in of water causes both embryo and surrounding food (endosperm) to swell and the seed coat to crack lengthwise. The appearance of the radicle through or near the hilum is again

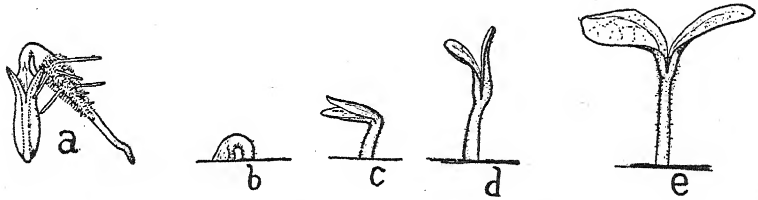


Fig. 7.—Different stages in the germination of the squash.

our first evidence of germination, followed by the elongation of the hypocotyl and the lifting of the cotyledons above the surface of the soil very much as in the case of the bean. However, the seed coats persist much longer than in the bean and the

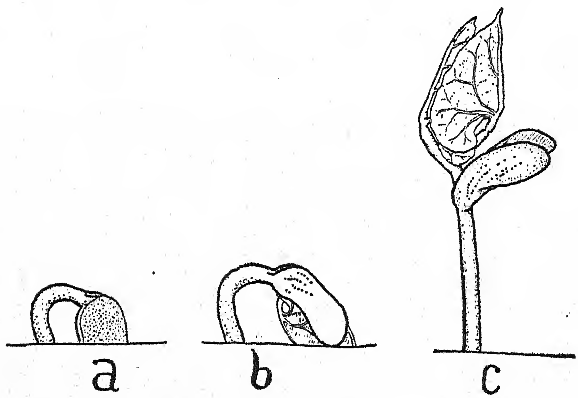


Fig. 8.—Bean seedling coming through the soil.

food is gradually absorbed by the cotyledons. As the food disappears the cotyledons gradually become green and leaf-like in appearance and function. They usually fall early, but are sometimes retained for a long time.

The first evidence of germination in the corn (Fig. 4) is the emergence of the root sheath enclosing the root which soon pushes through at the tip. This is quickly followed by the formation of side roots which really arise from the stem. Immediately following the emergence of the root sheath, the conically rolled leaves (plumule) push out from the opposite end of the groove and grow upward. The single cotyledon acts as an organ of absorption, the same as in the castor oil seed but does not rise above the surface of the soil and take on foliage characteristics.

The primary root elongates rapidly and produces an abundance of minute root-hairs (Pages 25 and 26), which serve for the absorption of water and nutriment from the soil. The stem elongates and new leaves are produced.

We have seen that the cotyledons serve different functions in different seeds; *i.e.,* for storage, for absorption and for foliage. A careful study of the characters of the seeds of a large number of plants and their germination will prove both instructive and interesting.

EXERCISES WITH SEEDS AND SEEDLINGS

1. Take a few dry beans and a few that have been soaked in water for three or four hours. Note the shape, the point of attachment (hilum) and the small opening or micropyle near it. Remove the seed coats and note their horny character. Note the two large cotyledons; they are connected by the short radicle which gives rise to the first root and the first stem or hypocotyl. Note the plumule or first bud lying between the two cotyledons, just above and attached to the radicle. Make drawings or diagrams, to show all these points.

2. **Castor Bean Seeds.**—Examine a few castor beans and compare with the beans. Note the thick bodies (caruncles) at point of attachment. Remove the seed coats. Make a careful examination and locate the embryo. Compare the cotyledons with those of the bean and note that they are thin and leaf-like. Note the character of the surrounding material. In what way is this seed like the bean? How is it different? Make drawings or diagrams and label the parts.

3. **Corn Kernels.**—Take a few dry grains of corn and a few that have been soaked in water for a few hours. Hold each grain with the groove towards you and the point or cap downwards. Note that it is covered with a thin horny coat which can be removed. Within the groove is the young plant or embryo with the root pointing downward. The stem is partly surrounded by a single leaf or cotyledon The entire embryo is surrounded by starch. The remainder of the grain consists primarily of two other forms of starch varying in amount in the different varieties. Cut some of the grains lengthwise and some in cross section, and examine the relationship of the various parts. Make a series of drawings or diagrams to show the preceding points.

4. **Write a comparative description** of these three types of seeds.

5. **Examine a number of other seeds** and group them with some of the above groups or types.

6. **Absorption of Water.**—Weigh a small quantity of dry seeds, place in water for a few hours and weigh again. What is the percentage of loss or gain in weight?

7. Fill a tall bottle or tube with dry seeds and add enough water to cover them. Mark the level of the water at the end of one, two, three, four and five hours respectively. Explain.

8. Fill a test tube or a bottle or a glass fruit jar with dry beans, tie a strong cloth over the top and immerse in water over night What is the result? Why?

9. Remove the seed coats from a quantity of dry beans and weigh without the coats; weigh out an equal amount of dry beans without removing the seed coats. Put the two lots in water for one hour. Compute changes in weight. Put in water for an additional hour and again compute changes in weight Explain.

10. Take two lots of dry beans of equal weight. Cover the micropyles of one lot with varnish or shellac and put both lots in wet sand for two hours. Weigh each lot and compute changes in weight. Explain.

11. **Germination.**—Plant a quantity of corn, beans, peas, melon, squash, cucumber and such other seeds as may be desirable, in clean sand. Remove a few seeds at intervals of three or four days. Make drawings, label the parts and write descriptions and comparisons. (Or, plant the seeds at intervals of three or four days for two or three weeks and then study the seedlings at various stages of growth at the same time.)

12. Cut a small slice off one side of several grains of corn. Germinate these with an equal number of uninjured grains between sheets of blotting paper. Is there any difference in time of germination? Why?

13. **Influence of Moisture, Heat and Light.**—(*a*) Plant two or three kinds of seeds in wet sand in a flower pot and keep in a warm, well-lighted place.

(*b*) Plant as in (*a*) but keep in a warm, dark closet.

(*c*) Plant as in (*a*) but keep in a cool, well-lighted place.

(*d*) Plant as in (*a*) but use a glass vessel instead of a flower pot, completely cover with water and keep in a warm, well-lighted place.

Examine all the above from time to time to determine the moisture, heat and light requirements. Write an account of results with explanations.

14. Plant seeds in a pot, keep well watered in a warm place, but covered with a box permitting the entrance of light from one direction. (The interior of the box should be painted black.) Note the direction of growth of the various parts. Explain.

15. **Work of Cotyledons.**—Plant several beans in a pot and keep in favorable condition for germination. As soon as the seedlings appear above the surface remove one cotyledon from each of one-third of the plants, and both cotyledons from each of one-third of the plants. Take note on the growth of the three sets of plants for several days. Explain difference.

16. **Water Requirements for Growth.**—Select two flower pots of the same size and weight. Cans with holes in the bottoms may be used. Secure enough garden soil to fill them; sift to remove all pebbles and mix thoroughly to secure uniformity of character. Fill the two pots with equal amounts (by weight) of soil. Plant six or more kernels of corn in one and set both in a warm, light place.

17. Set an ordinary piece of window glass in one side of a deep box. Fill the box with soil and plant seeds at various depths against the glass, so that their growths can be observed from the outside. Cover the glass with black cloth or paper, so that it can be easily removed for observation. Supply the necessary amount of water, keep in a warm place and note the germination and growth from time to time. What is the proper depth for planting seeds of this kind?

18. Partly fill a cigar box with wet sand. Cover the sand with a cloth that has been ruled into squares. Place a certain number of seeds in each square. Cover with a wet canton flannel cloth, and put in a warm place. Examine after forty-eight hours and estimate the percentage of germination. Make a second estimate after ninety-six hours. (This experiment should be tried with a number of different kinds of seeds from various sources.) How can seed testing be made of advantage to the farmer?

19. Put a few beans and a little water in each of two bottles. Fill one bottle with oxygen and the other with any other kind of gas. Close both in such a manner as to prevent the escape of the gas. Note the germination.

20. **Gas Formed During Germination.**—Put a few beans and a little water in each of two bottles. Stopper one with a good cork and leave

the other open. After 24 hours test both with a burning match. What is the result? Explain.

21. Repeat, but instead of testing with a match pour a little lime water into each. What is the result? Explain.

QUESTIONS

1. What are the three most important parts of the seed?
2. What are the parts of the embryo?
3. Why are the seeds of many plants valuable as food for man and animals?
4. Make a list of seeds used for food by man.
5. What are the two main classes of seeds and what are their characters?
6. In what part or parts of the seed is the food stored?
7. What are the functions of the cotyledons?
8. What are the hypocotyl, the radicle, the epicotyl, the hilum, the raphe, the micropyle, and the caruncle?
9. What are the necessary factors for seed germination?
10. Make a list of seeds that are planted in the spring.
11. Make another list of seeds that are planted in the fall.
12. What does the sprouting seed obtain from the air?
13. What is the effect of too much water on field crops?
14. When a seed sprouts, what part comes through the seed coat first?
15. When corn sprouts, what part is the first to appear above ground?
16. When a bean sprouts, what part is the first to appear above ground? What is the second part?
17. When a pea sprouts, what part is first to appear above ground?
18. What are the functions of the cotyledons? Give illustrations.
19. To what can we attribute the rapid germination of the seed?
20. What are enzymes?
21. Are enzymes found in the animal body?
22. If so, name a few of them and give their functions.
23. What do you mean by "seedling plant"?
24. What is the function of the micropyle?
25. What part of the seedling bean stem is the first to elongate?
26. Compare the cotyledons of the common bean and the castor oil plant.
27. Describe the opening of the seed coats of the bean, castor oil plant and other seeds.

CHAPTER II

ROOTS

We all know that plants have roots, but they are usually buried in the ground and thus hidden from sight and are not especially attractive. Therefore, most persons prefer to study the more prominent and pleasing parts of the plant. However, no part is of greater importance to the plant as a whole than the root system. When the seed sprouts, the root is the first organ of the embryo to break through the seed coats. (Figs. 2 *d,* 4, 6 and 7 *a.*) It grows downward, away from the light, but into the soil which contains the food and water. This tendency to go downward is called *geotropism.*

The soil should contain the necessary supply of food and moisture, and should be of such character that the roots can penetrate it readily if the plant is to make its normal growth. But we shall learn later that all plants do not require the same amounts of moisture, nor the same amounts and kinds of food. The farmer cultivates the soil for his crop plants and thus aids the plants in the work necessary for their growth.

Extent of Roots.—The root usually grows very rapidly, and when the entire root system is compared with the parts of the plant above ground, it is found to be much more extensive than we have ever imagined. When we pull a plant from the soil a very large number of the roots are broken off and left behind. Therefore, we get a very imperfect idea of the root system and its ramifications in the soil. But if a plant is grown in a pot of loose soil, and this soil carefully washed from the roots we begin to have some slight idea of the very great value of this part of the growing plant. It has numerous branches,

many of which have a delicate hair-like growth. The total length of all the roots of some plants may be many times the total of the stem and branches. The total length of all the roots of a mature oat plant are said to aggregate 154 feet, and those of a mature corn plant 1320 feet. Of course, no one root is likely to be more than a few feet in length. However, some plants are known to produce individual roots of considerable length. The alfalfa is said to produce single roots as much as 31 feet in length and the mesquites of the dry western plains are said to produce individual roots of as much as 60 feet in length. The greater the root surface, the greater the amount of food and water that can be secured by the plant. Of course, an increase of the root system is usually necessary to an increase of the part above ground.

The roots serve many purposes in the life of the plants, but these duties are somewhat variable for different plants. The most important functions are as follows: anchorage, gathering of water and food, storage of water and food, and in some cases for climbing. The roots serve as an anchor by which the plant is held in place. When we try to uproot a plant or think of the terrific wind storms to which our trees are frequently exposed, we can appreciate the importance of a secure anchorage. Some of the large trees of California are said to be thousands of years old and, after battling with the storms of ages, are still standing, objects of great admiration.

Gathering Food and Moisture.—We know that the roots are organs through which water and much of the food materials enter the plant, but we have very little idea of the amount of water and food necessary for plant growth. Our land plants require enormous quantities of water (Page 105), which must enter through the roots. Therefore, it is necessary for the roots to spread through the soil in such a manner as to reach

both water and food. The soil food is dissolved in the water, and the two usually enter the plant at the same time.

The thick, fleshy roots which are characteristic of some plants, such as the turnip, beet and radish, serve for the storage of food and water. Roots of this kind are used extensively for food by man and animals. The roots of some plants, such as the poison ivy, serve for climbing.

Forms and Arrangements of Root Systems.—The roots of a plant are not as irregular as many persons suppose; they assume forms and arrangements which are nearly as definite as the parts above ground. These forms and arrangements are just as characteristic of many plants as the stems, leaves, flowers and fruits. The roots of some kinds of plants go deep into the soil, while the roots of other kinds spread out, forming a mat just below the surface.

However, the arrangement of the roots of plants of the same kinds will vary somewhat with the character of the soil. The most important soil characters which influence the arrangement of roots are texture, depth, fertility and amount of moisture content. In general, it may be said that in shallow soil the roots will spread near the surface of the ground, while in deep soil they will tend to lie deeper; in rich, moist soil they will be short and branching, while in poor, dry soil they will be long and with few branches. However, some plants by nature tend to spread their roots near the surface, while others, like alfalfa, tend to go deep into the earth and are, therefore, especially well suited for certain soil conditions. Some crops require much deeper and richer soil and much more thorough cultivation than others. The potato and other plants with large, fleshy, underground structures require loose, deep, rich soil to thrive and give the best results. A knowledge of this relationship between root systems of plants and soil conditions is of very great value in selecting crops for different localities.

The roots of some plants are fibrous (Figs. 9, 10 and 13), and in large plants very woody and hard, while the roots of other plants are thick and fleshy. (Figs. 11 and 12.) The fibrous roots branch irregularly and serve for anchorage and also for the entrance of water and dissolved food materials.

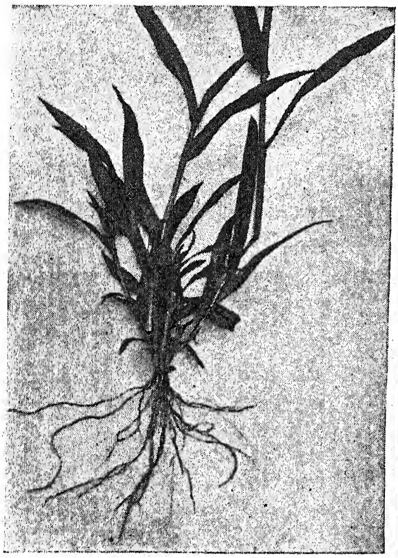


Fig. 9.—A grass plant showing the fibrous root system.

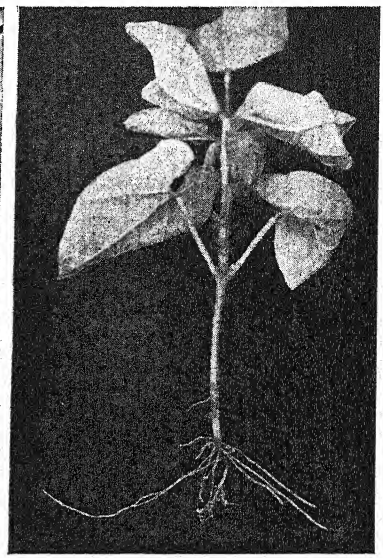


Fig. 10.—A bean seedling showing the bacterial nodules on the roots.

The fleshy roots, in addition to this work, also serve as places for storage of large quantities of foods. Man and animals take advantage of these stored products and use the roots of many plants for food. However, this food is stored in the roots for the future use of the plants themselves and is usually an important factor in their production of flowers and seeds. (Page 52.) Some plants use this stored food the same season that it is accumulated, while others hold it in reserve for one or more

years. The radish is a plant in which the food is used for seed production the same season that it is stored. The turnip develops the fleshy root one year and uses it for seed production the second year.

Food for Man.—The supply of stored food in the roots of many plants makes them valuable for food of man and other

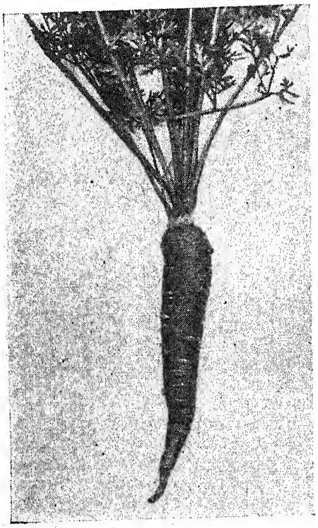


FIG. 11.—Carrot showing fleshy root.

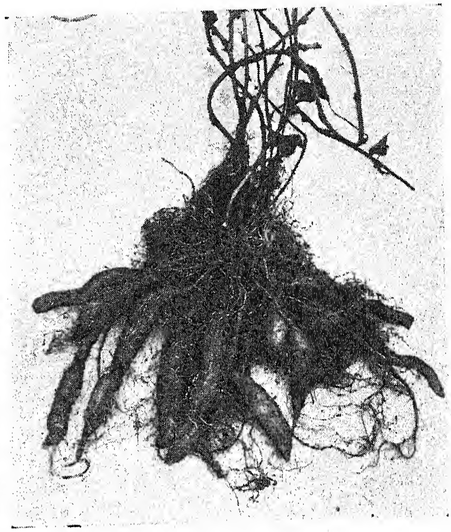


FIG. 12.—Sweet potato showing cluster of fleshy roots.

animals if used before they start to form the shoot for flower and seed production. But if we wait until this shoot is well advanced, we find the root becoming dry and pithy, owing to the loss of moisture and food which has been passed on into this new growth. In some plants, this storage for future use is performed by the stems or leaves. (Page 51.) The sweet potato (Fig. 12) is a plant which seldom produces seeds in our northern latitude, but uses the accumulated food of the large

fleshy roots for the immediate production of new plants or slips. Sometimes, new plants are also produced directly from fibrous roots, as in the case of the poplar, plum, etc., but as a rule new plants are not produced from the roots.

Length of Life.—Plants which live but one year, as in the case of the radish are known as *annuals;* those that live for two

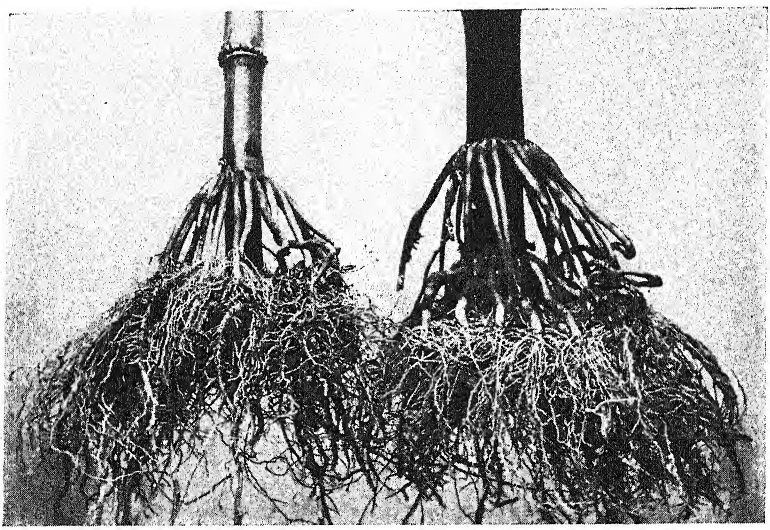


Fig. 13.—Corn plants showing the aërial roots.

years, as in the case of the turnip, are known as *biennials;* while those that normally live for several years, as in the case of trees, are known as *perennials.*

Aërial Roots.—Roots are frequently borne on parts of the stem above the ground, and are known as *aërial* roots. (Fig. 13.) These roots tend to reach the soil and serve as prop roots and help to support the plant against wind storms. They are well developed on the lower part of the corn, and are especially prominent on those plants which have not been tilled properly.

The Banyan tree of the tropical East Indies produces roots from its branches which tend to reach the soil and finally assume the character of tree trunks. Some plants, known as *epiphytes,* especially abundant in warm, moist climates, often produce aërial roots which never reach the soil but spread out into the moist air and serve for the absorption of water. The orchids of tropical countries, and the so-called Florida moss of our own Southern States are striking examples of epiphytic

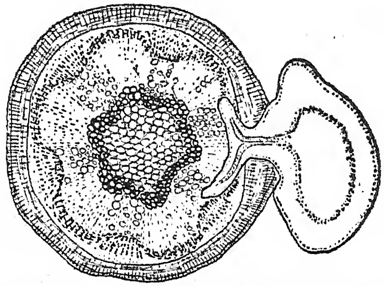


FIG. 14.—Cross-section of stem showing dodder attached by haustoria or parasitic root.

plants. The orchids in the colder climates are rooted in the soil.

The aërial roots may also serve for climbing on trees, fences or buildings, stone walls and other firm objects. *Climbing* plants are frequently injurious to trees, not only because their roots penetrate the minute crevices, but also because they retain the moisture and make favorable conditions for organisms which cause decay. They are also injurious to wooden structures on which they are allowed to grow, in that they retain moisture and cause decay.

Parasitic Roots.—Some plants feed upon other plants by means of roots which penetrate them. They are called *parasites,* and their roots *parasitic roots* or *haustoria.* The mistletoe of the South and the common dodder (Fig. 14) which is much

more widely distributed throughout the country are good illustrations of this type of roots.

Aquatic Roots.—Some floating plants produce roots which never penetrate the soil. They are known as *aquatic* roots and absorb water and the various food substances in solution which are necessary for plant growth. The very small but widely distributed duck weeds and the much larger water hyacinth of the South are excellent examples of floating plants. However, many aquatic plants, such as the pond lily, cat-tails, etc., have roots which penetrate the mud, while the plant either floats or stands upright.

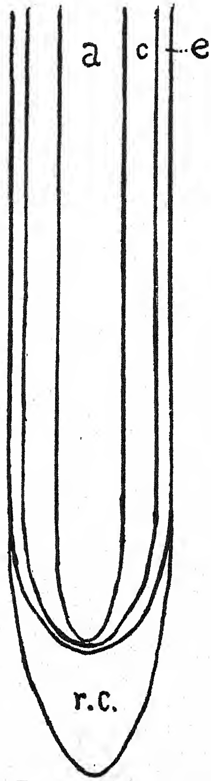


FIG. 15.—Diagrammatic longitudinal section of a root tip; a, central cylinder; c, cortex; e, epidermis; r. c, root cap.

Structures.—Roots are made up of three parts, a *central cylinder* composed primarily of woody tissue and surrounded by a sheath or *cellular cortex,* and covered with a very thin *epidermis* or skin-like coating. (Fig. 15.) They grow in length much more rapidly than in thickness and the very delicate tip is protected by a mass of cells known as the *root cap.* All parts of the root do not elongate with equal rapidity. There is a zone just back of the tip in which the growth is most rapid. The tips of roots are soft and delicate and easily broken, yet they must exert an enormous force which we cannot appreciate. The surface of the young roots, just back of the tip, is covered with numerous very delicate root-hairs or *trichomes.* (Figs. 4, 16 and 19.) These root-hairs are very numerous and should be studied on very young plants that have been grown in

a germinator, and also on plants that have been grown in loose soils. They grow between the very fine particles of soil. If the plant is pulled from hard soil they are torn off, but if pulled from loose, wet soil, they are retained and the soil clings to them. In order to understand them it will be necessary to study them with a microscope.

FIG. 16.—Seedling showing soil held by root-hairs.

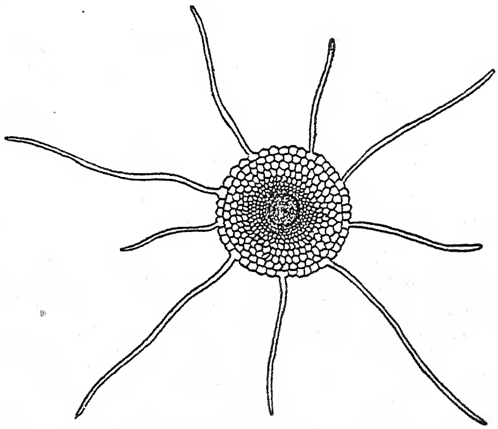


FIG. 17.—Cross-section of rootlet showing root-hairs.

Work of Root-Hairs.—Each root-hair is a thin-walled cell containing *living protoplasm* and cell sap. This living protoplasm has the power of absorbing water by osmosis, causing the cells to become very much expanded or turgid. The excess of certain substances in the soil may cause an exosmosis or withdrawal of water from the roots and thus injure or even kill the plant. This explains one reason why certain soils may be

unsuited for certain plants and also how the farmer may injure his crops by using too much of certain fertilizers or by the improper mixtures of the fertilizers with the soil. The root-hairs persist for a very short time and then perish, but new ones are produced near the growing tips. The number of root-hairs varies with the amount of water in the soil. They are more numerous in dry than in wet soils. (Figs. 17, 18 and 19.)

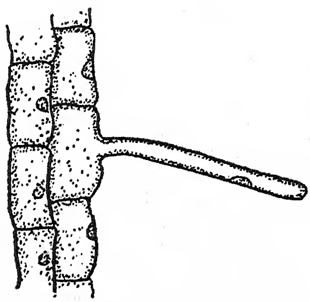


FIG. 18.—Showing attachment of root-hair to epidermis.

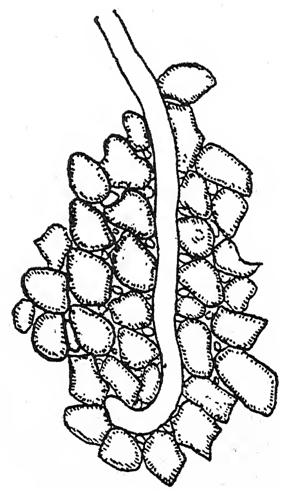


FIG. 19.—Showing relation of root-hair to soil particle.

Aided by Other Organisms.—Plants are frequently facilitated in securing their food by other organisms. Dead plants, dead animals and manures must undergo a decay before they are sources of available food for most plants. This decay is caused by bacteria and fungi. (Page 172.) Certain bacteria also aid the plant by taking the nitrogen from the air and fixing it in such a manner as to make it available for plant food. (Page 117.)

Roots of Plants Require More or Less Air.—The securing of this air is facilitated in many of our cultivated plants by drainage and by cultivation of the soil, thereby keeping it loose so that the air penetrates it readily. But plants growing in a state of nature have various parts and organs through which the necessary air is secured. Many aquatic plants, such as pond lilies and cat-tails, have air passages by which the air passes from the parts exposed to the air to the submerged parts. The swamp cypress has peculiar upward root growths known as "knees," which project above the surface of the water and serve for the absorption of oxygen. Many forest trees have root growths extending above the surface of the soil which serve for the same purpose. The filling in around trees which is frequently necessary in making grades is injurious because it prevents the air from reaching the roots.

EXERCISES WITH ROOTS

1. **Direction of Growth of Roots.**—Sprout a number of seeds and suspend in a moist chamber on long pins or by means of threads so that the root tips will point in different directions. Examine from day to day and note the direction of growth. Small moist chambers can be made by putting a small amount of water in a wide bottle or glass jar; run a hat pin through the cork for supporting seeds.

2. **Direction of Growth in Soil.**—Sprout a number of seeds and plant in wet sand in such a manner that the root tips point in different directions. Examine one a few days later and note the direction of growth of roots and stems.

3. **Growth Against Resistance.**—Partly fill a small cup with mercury. Pour a little water on the surface. Fasten a germinated seed in such a manner that the root tip rests on the mercury. Inclose in a moist chamber for 24 hours. Has the root tip penetrated the mercury? Does this require force?

4. **Geotropism or Direction of Root Growth.**—Sprout a number of beans in sphagnum moss or other loose material that will insure the formation of straight roots. Mark the roots into short, equal sections, using India ink, pin them to corks and place in large moist chambers * in such

* Moist chambers can be made by lining large battery or other glass jars with wet filter paper and covering so as to prevent excessive evaporation.

a manner that they will point in various directions. Examine at the end of 24 hours and again at the end of 48 hours. Note the direction of growth, the point at which curving begins and where the curvature is greatest as indicated by the marks and the point at which the greatest growth occurs.

5. Examine the root system of a growing bean, castor bean, or sunflower. Note the tap root, the mode of branching, the location of oldest and youngest branches, size and shape of tap root and branches. Make drawings or diagrams.

6. Examine the root system of growing corn, wheat or oats. Compare the root system with that in Ex. 5. Make drawings or diagrams.

7. Examine the root system of a growing beet, turnip or radish. Note the tap root and its branches Compare with that in Ex. 5. Make drawings or diagrams.

8. Examine the root system of the dahlia or sweet potato. Compare with that in Ex. 7. Make drawings or diagrams.

9. Examine the root system of English ivy or some other plant or plants in which the roots serve for climbing. Note their location, branchings and general character. Make drawings or diagrams.

10. **Region for Root-hairs.**—Sprout a number of grains of corn, okra, radish seed, clover seed, or white mustard, between wet blotting paper until the roots are about one and one-half inches in length. Note the region on which the root-hairs occur. Examine the root-hairs under a compound microscope, or strong hand lens.

11. **Soil Held by Root-hairs.**—Plant seeds in fine, sandy soil. After two weeks wet the soil thoroughly and very gently remove the plants. Note the manner in which the soil is held by the root hairs.

12. **Roots from Willow Twigs.**—Cut a number of willow twigs about twelve inches in length and put in a jar of water so that about half the length will be covered. Put part of them upside-down. Use an earthen jar or a glass jar covered with black paper so as to exclude the light. Examine from time to time and note the formation of roots. Where are they located and what is the direction of growth?

13. **Osmosis with a Thistle Tube.**—Make an artificial root-hair by covering the large end of a thistle tube with an animal or plant membrane, piece of intestine (sausage covering) or bladder, fill the bulb with a thick syrup (molasses) and invert in a jar of water so that the two fluids stand at the same level. Examine after a few hours and note the rise of the fluid in the tube. This passing of a fluid of less density through an animal membrane into a fluid of greater density is called osmosis. (Pages 112 and 113.)

14. **Osmosis with an Egg.**—Remove the shell without breaking the skin from the large end of an egg over an area about the size of a dime. In the same manner remove a small bit of shell from the small end over

an area about one-eighth of an inch in diameter. Run a glass tube through a small section of a wax candle and directly over the small opening. Now push the wire down the tube and puncture the membrane at the small end of the egg. Fill a wide-mouthed bottle level full of water and set the egg in the top. (Fig. 80.) Note and explain the rise of water in the tube.

15. **Osmosis with a Fleshy Root.**—Cut a slice from the upper part of a carrot or other fleshy root; hollow out the centre of the root and fill with sugar. Let stand for twenty-four hours. What has occurred? Explain.

16. Cut thin strips, about one-eighth inch thick, of a fleshy root and place in salt water for a few hours. Examine and then place in distilled water for a few hours. Examine and explain.

QUESTIONS

1. Where do we find the root system of the plant?
2. What do you understand by geotropism?
3. What are the characters of the soil that make it suitable for plant growth?
4. What can you say about the different types of root systems of plants?
5. What are the functions of the roots?
6. Is there any difference in the arrangement of the root systems of plants? Explain.
7. Upon what is the variation of the root system dependent?
8. What is the difference between the root system of the radish and that of the turnip? What functions do they serve?
9. Give a list of plants whose roots are used for food by man and livestock.
10. Define and give examples of annuals, biennials, and perennials.
11. What is the difference between aërial and epiphytic roots.
12. Name some plants with parasitic roots.
13. Name some plants with aquatic roots.
14. Name and locate the three parts of a root.
15. Explain osmosis.
16. Why are some fertilizers injurious to plants?
17. How does air reach the roots of plants? How can the farmer aid plants to secure air?
18. What is the general direction of root growth? Of stem growth?

CHAPTER III

STEMS AND BUDS

THE stem is that part of the plant which connects the root with the leaves. The most common types of stems of seed-bearing plants are above ground and serve to support the foliage and flowers. They usually show more or less well-defined divisions into nodes (joints), and internodes as indicated by branches, leaves and leaf scars, buds and bud scars. (Figs. 20 and 21.) They produce branches at the nodes more or less regularly. At the points where the new season's growth begins we find a number of scars very close together. (Fig. 20.) By examining the scars we can usually determine the amount of growth of the twigs for several years past.

There are two well-defined types of stems, the *exogenous* (Fig. 22 *a*), or the outside growing, and the *endogenous* (Fig. 23 *a*) or inside growing. The former is much more abundant than the latter, and the two can be readily distinguished by cutting them in cross sections. In both cases the stems are composed of hard, woody bundles surrounded by a softer substance which is covered by the bark or protective covering. The arrangement of these bundles is quite different in the two classes. In the exogenous stems (Fig. 22) the bundles are almost always arranged in a circle and the strength of the stem depends, in a large measure, on their compactness. Such stems will increase in diameter as long as the plant is alive and growing. This increase in diameter is due to the formation of a layer of wood just outside the last year's growth of wood. This very thin layer of cells in which the new growth is occurring is known as the *cambium*. These annual layers are so distinct that

they can be readily seen on the cut ends of tree trunks, with the naked eye, and are known as *annual rings.* (Fig. 24.) All the dicotyledonous and coniferous plants have stems of this type. If you cut a cross-section of a soft, rapidly growing stem (begonia or geranium), you can see these bundles more or less well defined. If you cut a cross-section of a woody stem, you will readily recognize these bundles which are separated by radiating lines.

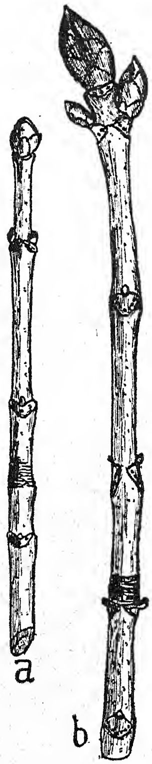


FIG. 20.—a, maple twig showing buds, leaf scar and annual growth; b, horse chestnut twig showing same.

We find two types of endogenous stems. One which consists of a mass of soft, pithy tissue surrounded by a hard rind and containing scattered, woody strings known as fibro-vascular bundles (Fig. 23), and another which is of the same general character, but is hollow, and therefore the fibro-vascular bundles are forced into the form of a cylinder. All of the grass stems are endogenous; the corn which is a coarse grass, is a good example of the first type and the various grains and most common grasses are examples of the second type. These fibro-vascular bundles or woody strings can be readily recognized in the corn stalk.

Stems in which the fibrous bundles are small as compared with the surrounding materials are soft and juicy, and are called *herbaceous,* while those in which the bundles constitute the greater part of the substance are called *woody.* Most of the strictly woody plants have exogenous stems and show rings. (Chapter VIII.)

Stems Above Ground.—The aërial, or above-ground, stems may be very short as in the case of the turnip or radish, in which

it supports a mass of leaves very close to the root and is known as a crown or *acaulescent* stem, or it may be more or less elongated, as in the case of many herbaceous plants and trees. The elongated stems may be erect, as in the case of trees, but extremely variable in size and form. Two well-defined types of

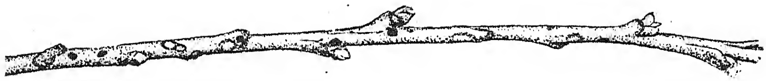


FIG. 21.—Twig showing alternate buds.

the stems are the *excurrent* (Fig. 25), in which we find a tree with a central axis or trunk giving off numerous small branches, like the pine, and the *deliquescent* (Fig. 26), in which the main trunk sub-divides by branching and loses its identity as in the oak and elm. Stems belonging to either of these types vary

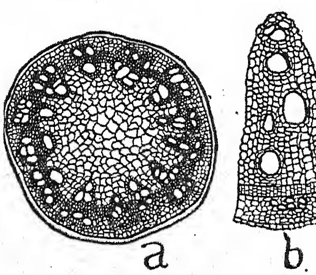


FIG. 22.—a, cross-section of dicotyledonous stem; b, fibrovascular bundle from same.

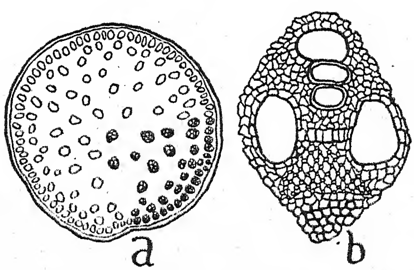


FIG. 23.—a, cross-section of monocotyledonous stem; b, cross-section of fibrovascular bundle of same.

greatly in the method of arrangement of the branches. Persons who have given some attention to this subject can recognize many trees by their style of branching.

However, many elongated aërial stems cannot stand erect, but are *decumbent*, or leaning, as in the case of many berry plants; or *prostrate*, as in the case of those plants which trail

3

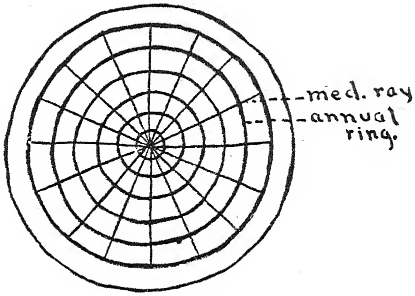


FIG. 24.—Diagrammatic cross-section of a tree stem showing the medullary rays and annual rings.

FIG. 25.—Trees showing the excurrent type of stems.

along the ground (ground ivy); or climbers, as in the case of many vines which cling to other plants, walls or buildings for support. Climbing may be accomplished by twining or by means of specially modified branches or stems (tendrils of

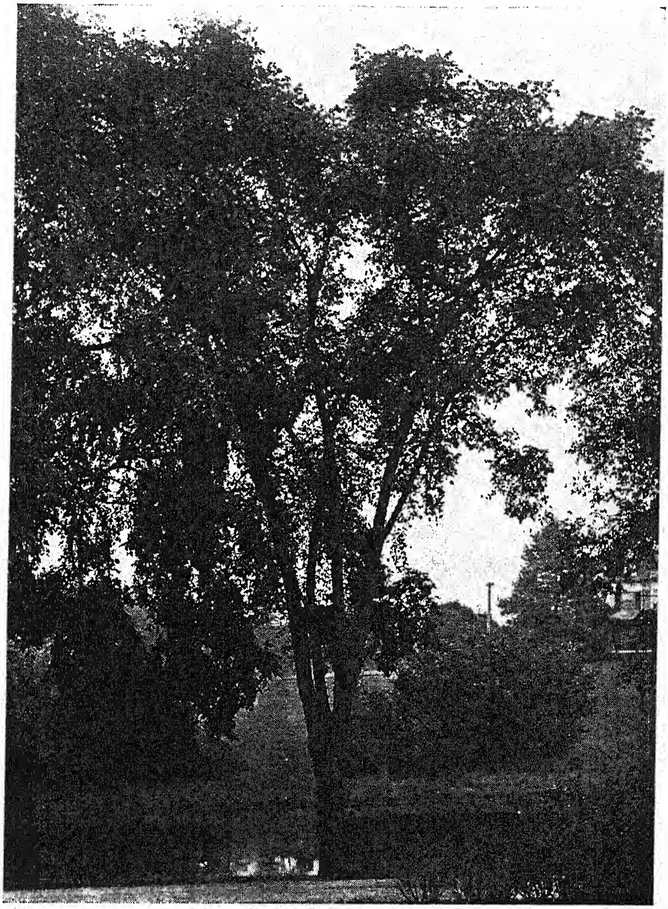


FIG. 26.—Tree showing the deliquescent type of stem.

grape), or by rootlets (poison ivy), or by modified leaves (clematis).

Underground Stems.—The stems of many plants are underground and are frequently mistaken for roots. However, they

can be readily recognized by the fact that, like all stems, they are divided into more or less regular nodes and internodes, and the branching is always from these nodes and is, therefore, regular, while the roots are without nodes and branch irregularly.

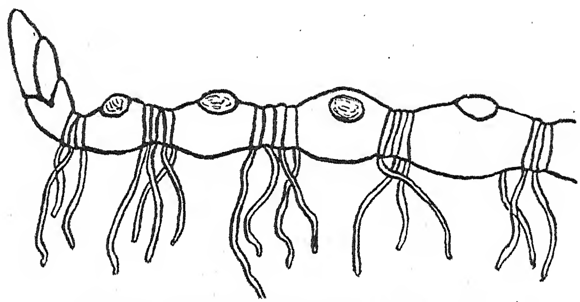


FIG. 27.—Underground stem of the Solomon's seal.

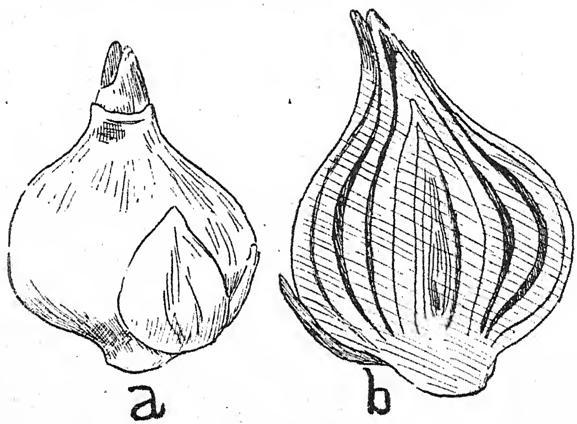


FIG. 28.—a, tulip bulb; b, same cut longitudinally to show short basal stem and fleshy leaf overlapping the single terminal bud.

Numerous roots are frequently formed at the nodes of these underground stems.

Underground stems may be divided into two general types, the elongated and the short. The elongated stems, which are so well illustrated by the Solomon's seal and May-apple (Fig. 27),

bear roots at regular intervals and show well-defined leaf scars at the nodes. Some grasses, such as the witch grass, have similar underground stems bearing buds at the nodes. When such grass stems are torn to pieces by the farm implements each

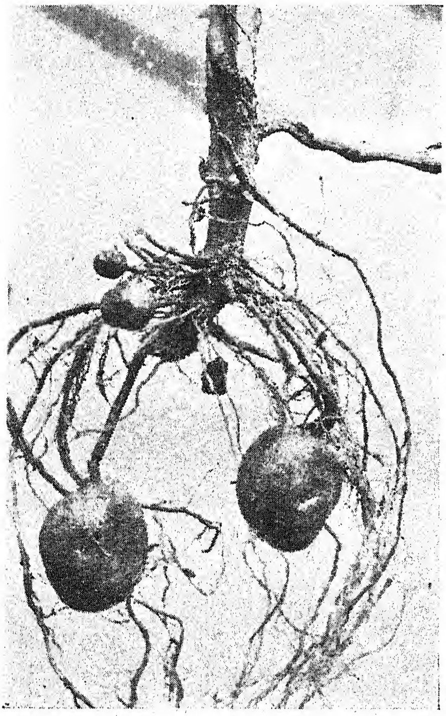


FIG. 29.—Potato showing the tuber type of stem.

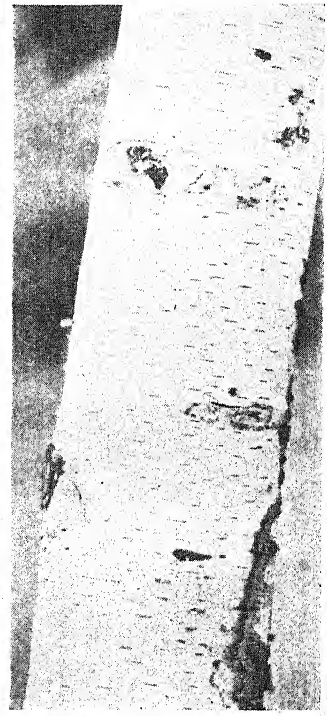


FIG. 30.—Stem or trunk of the birch showing the peculiar markings of the bark.

bud is capable of growing into a new plant. Such stems are called *root stocks* or *rhizomes.* Shortened stems have very short internodes and are generally designated as bulbs (Fig. 28) and tubers (Fig. 29). The bulbs are very short stems covered with scales which are really modified leaves. These scales may be

very prominent, as in the case of the hyacinth or onion, or they may be small and on a very short, thick, fleshy stem, as in the case of the Indian turnip. This last type is known as a corm.

Bulbs or bulblets are sometimes borne on the stem above ground; they are nothing more nor less than modified buds.

Sometimes the underground stems become very thick and fleshy and are known as tubers. The common white or Irish potato is an excellent example of the tuber. The so-called "eyes" are buds and indicate the nodes of the stem. True tubers, such as the Irish potato, are fleshy stems and are entirely different from the fleshy roots of such plants as the sweet potato and the dahlia.

Two Chief Uses of Stems.—As previously stated, stems connect the roots with the leaves and support the latter in the air and light, but some plants, such as the cactus, have leaves that are poorly developed and of little importance. The stems of these so-called "leafless" plants are green and serve the same function as leaves. (Page 47.) The stems of many other plants are also green and perform the duties of leaves for a part or for the entire life of the plants. The young twigs are usually green and have *stomata* (Chapter IV), the same as leaves. However, these stomata soon lose their original character, and develop into lenticles. (Chapter VIII.) The lenticles are the little specks which are so readily recognized on the smaller twigs. (Figs. 20, 21 and 30.) They will be referred to again.

Stems also serve for the passage of the water and food substances from one part of the plant to another. (Chapter VIII.) These are the primary functions of stems, but they also serve many other purposes. In the cacti and other plants living in very dry regions they serve for the accumulation of considerable quantities of water. Floating plants frequently have large chambers filled with air which increases their buoyancy. Many stems, such as tubers, serve for the accumulation of food sub-

stances for future use. Man has taken advantage of this fact and uses potatoes, onions and many other fleshy stems for food.

But one of the most important of the secondary functions of the stem is reproduction This is accomplished by underground stems, by the branching and the breaking-up of the root stocks, and by the budding or formation of bulblets in the bulb types. Many plants, lilies and hyacinths, have practically lost their power to produce seeds and depend entirely upon this method of reproduction. Irish potatoes are very generally grown from tubers, but they will occasionally produce seeds, and the wild potatoes of South America produce seeds very freely. The growing of bulbs of ornamental plants is a leading industry in many parts of the world. Holland is one of the greatest of the bulb-producing countries of the world.

Many aërial stems reproduce by runners and offsets and we depend largely upon this method of reproduction to secure plants for agricultural purposes. This is the regular method of propagating strawberry plants. Branches of many plants when set in the soil will produce roots and grow rapidly, and in nature broken branches of willows and many other plants catch in the soil or become partially covered and grow. We have taken advantage of this tendency and propagate many useful plants from cuttings.

The art of budding and grafting is based on this tendency of cuttings to grow under favorable conditions. Budding consists in setting the buds of one plant within the bark of another plant, and is generally used in propagating peaches, cherries and similar fruits. Grafting consists in setting a part of a living twig with its buds from one tree into the branch of another and is very generally used in propagating apples and similar fruits.

The structure of stems, their methods of growth and the movements of the plant juices through them will be taken up in a later chapter.

In the first chapter we learned that plants are made up of

but three primary organs, roots, stems and leaves, and that the other so-called organs with which we are so familiar are modifications of these three. We have already studied the roots and the stems, but before taking up the study of the leaves let us consider the *buds which are undeveloped shoots or stems.*

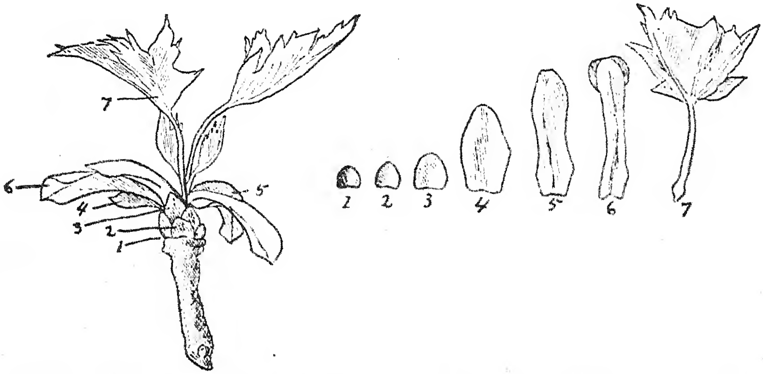


FIG. 31.—A newly opened leaf bud of the maple and the same bud dissected to show graduation from scale to leaf.

A leaf bud consists of a very short, undeveloped stem bearing a compact mass of minute leaves. (Figs. 20, 21 and 31.) This stem will elongate and the leaves grow to full size. It is then known as a stem or shoot with its leaves.

Flower buds are those which develop into flowers, but we will learn later that flowers are made up of modified leaves on short stems and therefore, it is not necessary to change our definition of a bud. (Chapter V.)

Location and Structure of Buds.—Buds are borne in the axils, that is just above the point of union of the leaf to the stem. In our northern climates they are produced a year in advance of their development into shoots or flowers and remain over winter in a dormant or resting condition. In temperate climates the buds are frequently spoken of as *scaly* buds because the lower or outside leaves are modified as scales and serve to

protect the true leaves and flowers within. These scales never develop into true leaves. The examination of the buds of many of our plants in the spring will show a gradual graduation from scales on the outside to well-formed leaves on the inside. (Fig. 13.) These outside scales are frequently covered with masses of plant hairs (trichomes) or with wax or have the appearance of being varnished. These structures serve as a protection against the entrance of water which would cause great damage, especially during the winter season. Many of the plants of warm climates and some of the plants of temperate climates have *naked* or nearly naked buds; that is, buds that have very little or no protection from the climatic conditions.

Buds are also classified with reference to their location on the stem. Those at the tip are *apical* or *terminal,* while those on the sides are *lateral.* Lateral buds may be *opposite* or *alternate.* When lateral buds are directly in the angle formed by the stem and leaf they are *axillary,* but when to one side or above they are called *accessory.* Buds borne on other parts of the stem, on the roots and on the leaves are known as *adventitious;* they are of the greatest importance in the propagation of plants by cuttings.

A plant cannot produce food for the growth of all of its leaf buds into shoots and, therefore, many buds perish, but some of them remain dormant and many later develop into the well-known sucker or water shoots. Such growths are very common on trees that have been over-pruned, or broken by storms. If it were possible for all the buds to grow, all our trees would assume the characters of very dense hedge plants. The tendency of some plants, such as the privet and osage-orange, to produce a very large number of shoots increases their value as hedge plants and ornamentals.

The growth of shoots from the buds may be *definite* or indefinite. The definite annual growths are those in which the

shoots increase in length for a few weeks only and the remainder of the season is used for maturing the wood and buds. Such growths are not likely to winter-kill, and the growths of successive years can be readily traced by the bud scars on the stem. The shoots of other plants grow throughout the entire season and until checked by the cold weather; they are known as *indefinite* growths, and are likely to suffer from winter injury. The roses, lilacs, sumac and ailanthus or tree-of-heaven are excellent examples of this type of growth.

Underground stems produce buds at the nodes in the same manner as the stems above ground. The so-called "eyes" of the potatoes are buds which give rise to shoots. The bulbs of many plants, although usually described as stems, are, in reality, buds.

EXERCISES WITH STEMS AND BUDS

1. **Study of Woody Twigs.**—Cut a branch from a maple, linden, horse chestnut or other dicotyledonous tree and note the *nodes* and *internodes* of the newest growth as marked by buds and scales; trace as many seasons of growth as possible, beginning with the tip of the twig. Examine the bark with a hand lens and note leaf scars, lenticles and other peculiarities.

2. **Monocotyledonous Stems.**—Examine a corn stalk, grass stem, grain straw and other monocotyledonous stems and compare with a woody stem studied in previous exercise.

3. **Cross-section of Herbaceous Stem.**—Cut through a Begonia stem (dicotyledonous), examine with a hand lens and note (*a*) the central mass or *pith* surrounded by (*b*) a circle of wedge-shaped areas which are fibro-vascular bundles of wood, and which are separated from each other by material like the pith and known as *medullary rays*. Outside the fibro-vascular bundles is another zone which is in turn surrounded by the *epidermis* or *bark* covering.

4. **Layers of Bark.**—Take the last season's growth of a lilac, horse-chestnut or maple. Gently scrape off the outer brown bark, the inner green bark and the fibrous bark and examine with a hand lens and note, (*a*) the outer brown bark layer, (*b*) the second or dark green layer of new bark and (*c*) the third layer of tough fibrous bark or bast.

5. **Cross-section of Woody Twigs.**—Cut through a woody twig of oak or basswood and note (*a*) the central pith surrounded by (*b*) the

wedge-shaped fibro-vascular bundles separated by (*c*) the radiating medullary rays and (*d*) the concentric circles or annual rings.

6. **The Parts in Large Timber.**—Examine the cut end of a large stem or tree trunk and note the same points as in the preceding exercise. Examine the ends of sawed timber and determine the above parts. Trace them in the long section of the timber.

7. **Rise of Sap in Stems.**—Stand the freshly cut stems of Begonia, horse-chestnut and other plants in water colored with eosin or red ink for 30 minutes, one hour, and for 24 hours. Cut off small pieces, beginning at the base and examine with a hand lens. Note the part through which the colored fluid rises and the height to which it has risen.

8. **Persistent Upward Tendency of Stems.**—Take an upright, potted plant and place in a horizontal position (pot and all). Makē a diagram to denote the relative position of the parts and examine again at the end of 24 and 48 hours.

9. **Dandelion Stem and Buds.**—Examine the short stem of the dandelion or similar plant. Count the number of buds you can find near the surface of the soil. Does the number vary with the size and age of the plant? Split the entire plant lengthwise and try to determine point of union between stem and root.

10. **Examine the under-ground stem** of Solomon's seal, May-apple, Johnson grass or similar plants and compare with an aërial stem.

11. **Examine the bulbs** of crocus, tulip, gladiolus, Indian turnip, onion, etc., and note their general character. Cut them open lengthwise and note the short stems and scale-like leaves.

12. **Examine a potato tuber** and note its general character. Note the arrangement of the eyes or buds. Compare with the fleshy root of a sweet potato. Cut through it and note the fibro-vascular bundles just beneath the epidermis or peeling.

13. **Buds of Twigs.**—Examine the stems of lilac, horse-chestnut, hickory and maple. Note number, arrangement and relative sizes of the buds on the different stems and on the same stem.

14. **Structure of Buds.**—Take the large buds of the lilac, horse-chestnut, hickory, etc., and carefully dissect by successively removing the scales and inner parts. Note the gradual transition from scales to leaves. Note the short, conical, undeveloped stem to which they are attached. Compare the bud to a scaly bulb. (This study is most satisfactory if conducted in the early spring when the buds are swollen. In winter the stems should stand in water a few days before the study.)

15. **Opening of Buds.**—Cut a few of the newest and most vigorous shoots from a lilac in winter or early in the spring before the buds open and place in water in a warm room. Examine from day to day and note the opening of the buds and growth of new shoots.

QUESTIONS

1. What is the stem?
2. What are nodes? Internodes?
3. Name and explain the types of stems.
4. Describe a cross-section of each.
5. Describe the outside coverings of a stem.
6. What are the annual rings?
7. What are the differences between herbaceous and woody stems?
8. What do you understand by acaulescent? Excurrent? Decumbent? Prostrate?
9. Explain the methods by which plants climb.
10. How can you distinguish underground stems from roots?
11. Describe a rhizome. A bulb. A tuber. Give examples of each.
12 What are lenticles?
13. What are the various functions of stems?
14. Read and give a report of the flower industry of Holland.
15. Read and give a report of the history of the potato.
16. Explain the natural methods of plant propagation by means of stems.
17. What are the artificial methods of plant reproduction by stems?
18. Compare a corn stalk with the stem of a woody plant.
19. What are medullary rays?
20. Through what part of the stem does water rise? How demonstrated?
21. When you examine the cut end of a large woody stem what do you see?
22. What occurs when plants are exposed so as to receive the sun on one side only?
23. What is the general direction of stem growth as compared with root growth?
24. Where do you find the fibro-vascular bundles in the tuber of the Irish potato?
25. Compare the tuber of the Irish potato with the root of the sweet potato.
26. What is a bud?
27. What is a flower bud?
28. Where are buds borne?
29. When are buds produced?
30. What do you understand by apical, lateral, opposite, alternate, axillary, accessory and adventitious buds?
31. Do all the leaf buds grow into shoots? Why?
32. What do you mean by definite and indefinite growths?
33. What are the eyes of the potato tuber?

CHAPTER IV

LEAVES

The leaves of a plant are always borne on the stem and have the same relative position as the buds. (Figs. 20 and 21.) They are the expanded parts of the plant and have a definite relationship to the air and sunlight.

Green plants must have an expanded surface (usually the foliage) into which the gaseous elements (Chapter X) of the air may pass. These gaseous elements are as necessary for the growth of the plant as are the raw food materials of the soil. These expanded parts contain chlorophyll or the green coloring material which is necessary for the formation of true food substances from the elements and compounds obtained from the water, soil and air.

Relation to Light.—If you stand under a tree and look upwards, you will note that the leaves are on or near the tips of the twigs and thus form a canopy or tent with the trunk and branches as the supporting framework. If you place yourself in such a position as to look down upon a small tree or other plant or at a vine (Fig. 32), climbing over a wall you will be surprised to note how very little the leaves shade one another, and that all have very nearly the same light and air exposure. The leaves of many plants, especially the legumes, are also raised and lowered to some extent throughout the day in such a manner as to receive the sunlight to the best advantage.

The leaves are the factories in which the raw food substances are transformed into true food substances for the growth of the plant. The water and these various raw or crude food substances which may be dissolved in it are taken from the soil

and carried to the leaves where the most of the water is transpired into the air. (Page 114.) The leaves take carbon dioxide gas (CO_2) from the air and as a result of the action of the sunlight on the green coloring matter (chlorophyll) these substances are transformed into starch. This process is known as

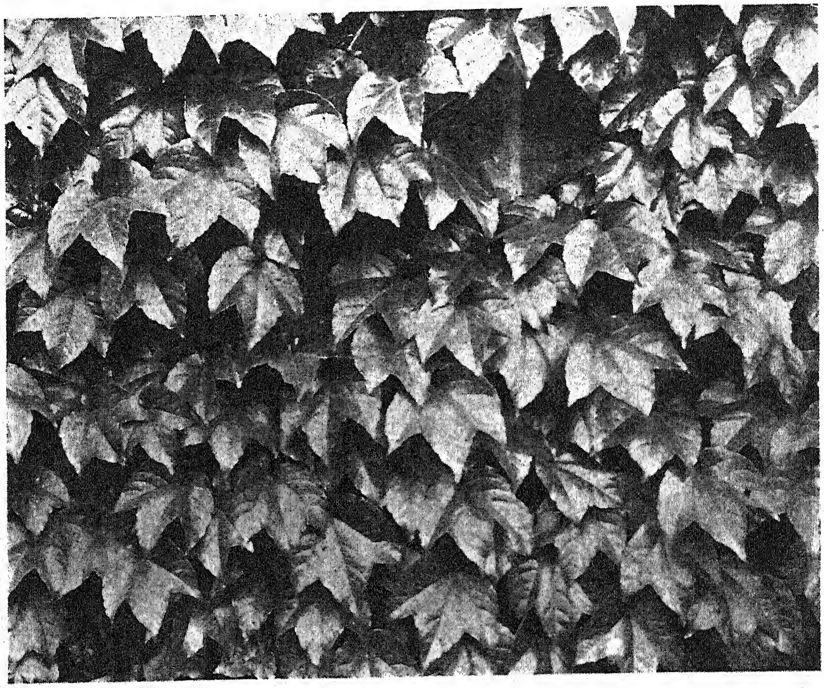


FIG. 32.—Ivy leaves on a wall showing the arrangement with very little overlapping.

photosynthesis (Page 115), which is the most remarkable process in all nature. It is the most important process in plant growth, and without plant life there could be no animal life.

Sunlight and Chlorophyll.—The formation of the complex food substances or compounds from the crude materials of the soil and air is accomplished in green plants only and, there-

fore, all animals and all plants that do not contain chlorophyll are dependent either directly or indirectly upon these green plants for their food supply. Different kinds of plants require varying amounts of light and, therefore, we find some plants growing in the direct sunlight, while others are usually found in the shade and will not thrive in the intense sunlight. We also notice that the arrangement of the foliage on the plant, and its

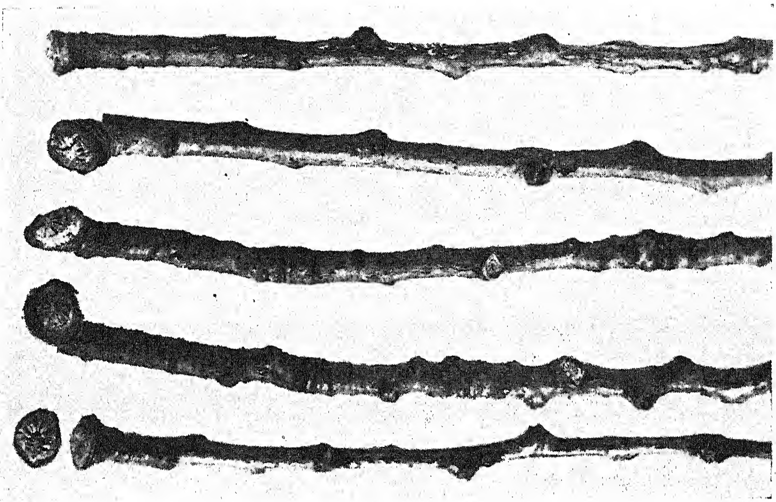


FIG. 33.—Self-pruned twigs of the poplar showing the cleavage planes.

position during different hours of the day and on cloudy and clear days, are such as to relieve the sunlight in proportions more or less suitable for its own work. Plants growing in the desert, or other dry places, may be "leafless" or have the leaves greatly reduced, but the *stems* of such plants contain the chlorophyll and serve as foliage. Plants may produce more foliage than is necessary for their normal growth. Such plants may drop individual leaves or even large shoots during the growing season by a process of self-pruning. These leaves and shoots are not

broken off but "grow off" by the formation of definite cleavage planes as in the shedding of leaves for winter. This self-pruning process is very common among willows, poplars, cottonwoods and many other trees. (Fig. 33.)

Parts of Leaves.—A simple, typical leaf (Fig. 34) has a *blade* or *lamella* supported by a framework composed of *ribs*

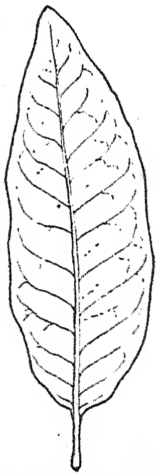


FIG. 34.—Simple net-veined leaf.

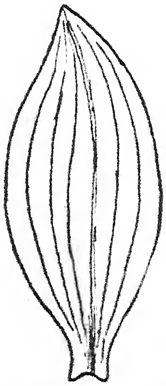


FIG. 35.—Simple parallel-veined leaf.

and *veins*. The principal rib is known as the *midrib* and is a continuation of the leaf stem or *petiole*. Leaves which do not have petioles are *sessile*. These ribs and veins are continuations of the woody bundles found in the stems and serve not only to support the leaf but as channels through which the water and raw food materials pass to the leaf, and through which more complex food substances pass to other parts of the plant. Minute structures, known as stipules, frequently are found at the bases of the petioles. They are extremely variable in form and character. Sometimes they are leaf-like and may fall soon after the unfolding of the leaves as in the willows; sometimes they are

attached along the margin of the petioles as in the clovers; sometimes they are developed as sheaths enclosing the stem as in the grasses and grains; and sometimes they enclose the young leaves as in the tulip tree.

Types of Leaves.—Leaves which have one prominent mid-

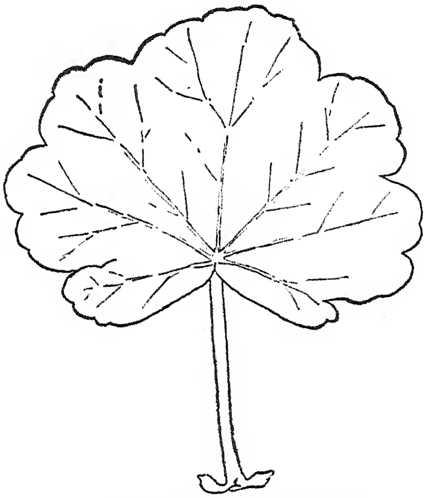


FIG. 36.—Palmately veined leaf.

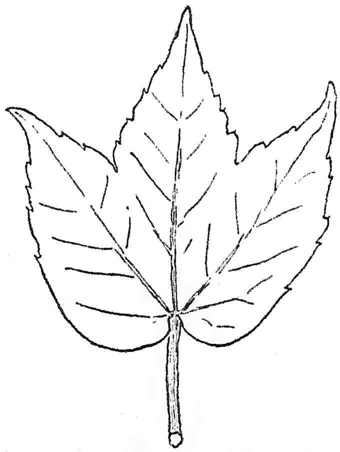


FIG. 37.—Palmately veined leaf.

rib running from base to apex, and giving rise to numerous side branches with smaller veinations between them are said to be *net-veined* (Fig. 34), while leaves which have a number of equally prominent veins running from base to tip are said to be *parallel-veined.* (Fig. 35.) Most dicotyledonous plants have net-veined leaves, while most monocotyledonous plants have parallel-veined leaves. Leaves which have three, five or more prominent ribs or veins arising from a common point are said to be *palmate-net-veined* or *radiate-net-veined* (Figs. 36 and 37), while those that have numerous veins arising from a main mid-rib are said to be *pinnate-net-veined* or *feather-net-veined.* (Fig. 34.)

Compound Leaves.—Leaves which are composed of two or more leaflets arising from a single petiole are said to be compound and are described as *palmate-* or *radiate-compound* (Fig. 38), or as *pinnate-* or *feather-compound.* (Fig. 39.) The size, form, arrangement and various other modifications of the leaves of plants are largely dependent upon the environmental factors,

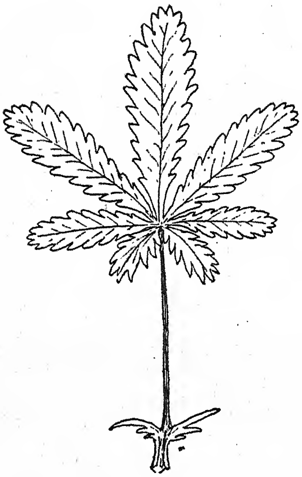


Fig. 38.—Palmately compound leaf.

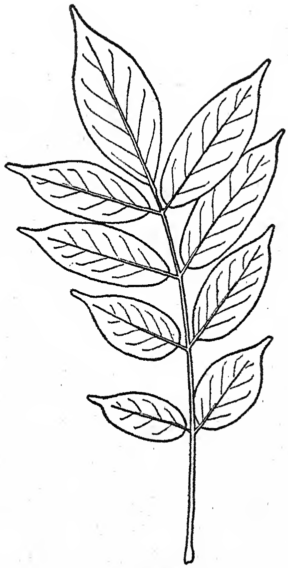


Fig. 39.—Pinnately compound leaf.

especially light and moisture. Land plants, growing in very wet surroundings tend to have larger leaves than those growing in dry or arid surroundings. Aquatic plants in running water tend to have long, narrow leaves as compared with plants living in still water.

The Leaf Blade.—The veination of the leaves supports a delicate structure (Page 102), within which are numerous air

passages with openings (stomata) to the outside, usually on the lower surface. These passages and openings facilitate the transpiration of water (Page 114), and the absorption of gases. (Page 115.) The texture of leaves varies largely with the environment in which they live. The surfaces of leaves are also frequently covered with spines, hairs (trichomes), gland hairs, wax, etc., which serve to protect the plant, prevent excessive transpiration and otherwise facilitate its work.

Uses of Leaves.—Leaves are so abundant, and come with such great regularity that we are likely to fail to appreciate their importance in the life of the plant. But these very commonplace facts should convince us that they are invaluable to the plant, that they are something more than elements of beauty in the individual plant or in the landscape. We have already learned that the primary function of leaves is to serve as foliage through which the living, growing plant receives gases from the air and energy from the sun and in which the raw food substances are transformed into true foods (photosynthesis, Page 115). But the leaves serve many other useful purposes which are important in the life history of the plant: (*a*) they are the organs of *transpiration* (Page 114), by which are given off quantities of water previously absorbed through the roots; (*b*) they are organs of *respiration,* although this function is not confined to the leaves; (*c*) they may serve as *bud scales* for the protection of the more typical foliage leaves and flowers (Page 40); (*d*) they may develop a bitter gum and thus serve as a protection against birds and other small animals which feed on the new growths in the early spring; (*e*) or they may develop as briars or thorns which, no doubt, serve to some extent as a protection against larger animals. Thistles and other plants which are armed with these protective structures will stand unmolested in the stock pasture, even though the food

supply for the cattle may be very limited. Every good farmer knows the advantage of using sheep or goats for the cleaning of neglected lands of these armed weed pests which most livestock will not touch.

Leaves also serve for the storage of food and water as in the case of the so-called "century plant," which grows for a number of years and then develops its flowers and seeds at the expense of the food stored in the large fleshy leaves. This is no more wonderful than the common cabbage in which exactly the same thing occurs in a cycle of two years; the accumulation of the food is during the first, and producing the flower and seed during the second year. Man has taken advantage of this tendency of the plant to store its food in the leaves and makes use of many such plants as food for himself. Leaves may also serve for the storage of air as in the case of the floating plants which contain large air-chambers.

In some few plants the leaves have undergone modifications, enabling them to serve as *insect traps* for the capture of insects which die, decay, and furnish a supply of nitrogenous food for the growing plant. The most interesting insect catchers are the sun-dew, Venus fly-trap, and the pitcher plants, which you will find described in an encyclopedia, and in many works on botany.

Probably the most important function of leaves after photosynthesis is the formation of flowers and fruits, for as we shall learn later, the flowers are modified leaves. (Page 54.)

EXERCISES

1. Collect the following forms of leaves: simple net-veined, simple parallel-veined, simple palmate-veined, compound palmate-veined and compound pinnate-veined. Make drawings and label the parts.
2. Collect and make drawings of leaves with and without petioles.
3. Collect leaves showing different types of stipules.

QUESTIONS

1. On what part of the plant are the leaves borne?

2. Why is it necessary that the leaves should be exposed to the air?

3. What are the sources of plant food?

4. Why is it necessary that the plant receive sunlight?

5. Why are animals dependent on plants for food?

6. Are there any other sources from which animals can secure food?

7. What parts of the plant other than the leaves may possess chlorophyll? Give examples.

8. Name the parts of a simple leaf.

9. What are the differences between net- and parallel-veined leaves?

10. What are the differences between simple and compound leaves? Give examples of each.

11. What are the functions of the leaves?

CHAPTER V

THE FLOWER

HAVING studied the three primary parts of the plant, the root, stem and leaves, we now turn our attention to the most important secondary organ, the flower. The flowers of many plants are objects of beauty, but the great majority of plants bear flowers which are very small and inconspicuous, or which are of such character that they do not attract the attention of the casual observer. Many people are so accustomed to thinking of flowers as mere objects of beauty that they fail to realize the very great importance of these organs in the life history of the plant. The flowers contain the sexual organs of the plant and are necessary for the production of seeds and fruits.

Parts of the Flower.—The flower does not present any new structures, but is a shortened stem bearing circles of leaves, which have been greatly modified in shape and color into parts constituting the flower. Instead of being borne on a long stem, they are now brought together in circles and the shortened stem is known as the receptacle, or *torus;* the first or outer circle, composed of parts which are usually green and resembling ordinary leaves, is known as the *calyx,* and each leaf-like part is called a *sepal;* the second circle or series of circles composed of parts which also have some resemblance to leaves but which are usually colored is known as the *corolla,* and each part is called a *petal;* the third set of organs consisting of one or more circles is composed of *stamens* which bear very little resemblance to leaves; the last or central group consisting of one or more organs which may be distinct or united is the *pistil* which also bears very little resemblance to leaves. (Figs.

40 to 44.) The *calyx* and *corolla* constitute the *floral envelope* or *perianth* while the *stamens* and *pistils* are the *sexual* or *essential* organs of the plant. The arrangement of the organs in circles permits the making of diagrams which represent the general plan of a flower as clearly as a map shows the physical

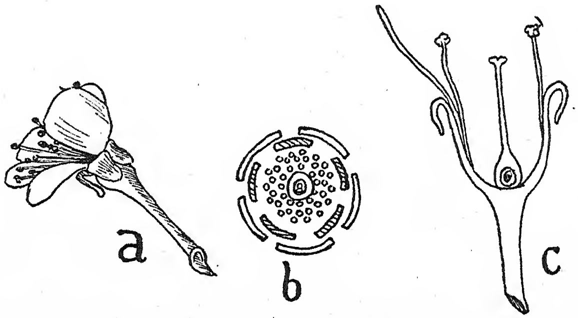


FIG. 40.—a, cherry blossom; b and c, diagrams showing the arrangement of the parts.

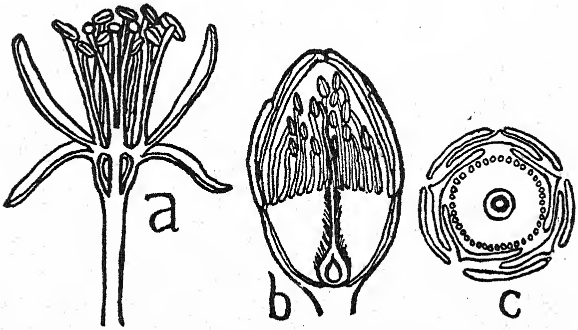


FIG. 41.—a, diagrammatic longitudinal section of apple blossom; b and c, peach blossom.

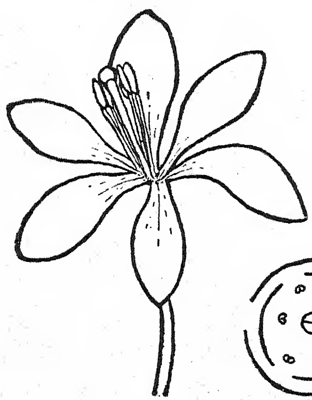
and political divisions of the earth. If this diagram is accompanied by a second diagram made at right angles to the first, the general architecture of the flower is well shown.

The *sepals* and *petals* being leaf-like in character sometimes grade imperceptibly the one into the other. In some flowers, of which many lilies are examples, the parts of these outer circles

are practically alike in both shape and color; while in other flowers there is no corolla. When the corolla is missing, the calyx may be green, but it is usually of some other color which deceives many observers into believing it to be the corolla. The common hepatica and the wind flower are good examples of flowers with colored calyx and no corolla.

When the corolla alone is absent, the flower is described as *apetalous* (*i.e.,* without petals). Some plants have flowers

FIG. 42



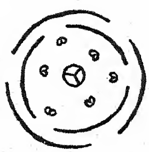


FIG. 43

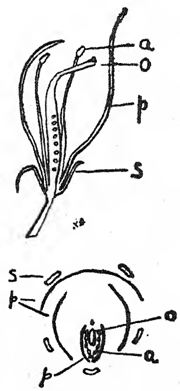


FIG. 42.—Diagrammatic drawing and cross-section of a lily.
FIG. 43.—Diagrammatic longitudinal and cross-sections of a pea blossom.

with neither calyx nor corolla, but these incomplete flowers are just as important in the life history of the plant as the very complicated and highly colored flowers of other species.

The stamens in most flowers are distinct and have no external resemblance to leaves, but in some flowers the gradual transition from petals to stamens is so apparent as to leave no doubt whatever as to origin, even in the mind of the most casual observer. This is especially well illustrated in the white water lilies. In a state of nature, we sometimes find flowers in which the petals assume stamen character or the stamens tend to

become petal-like in character. This tendency in plants makes it possible for the florist to develop double flowers from the natural single ones; the wild rose has but five petals, and numerous stamens, but the double rose has many petals and few or no stamens, they having been transformed into petals, more or less like the other petals.

The pistils are more distinct than the stamens but will sometimes assume petal-like characters. The organs of some

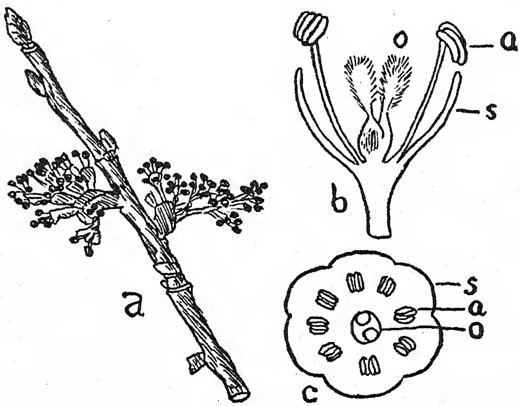


FIG. 44.—a, twig and two clusters of elm blossoms; b and c, diagrammatic longitudinal and cross-sections of a single blossom.

flowers are imperfect and of no use to the plant. If all of the stamens or all of the pistils are imperfect the plant cannot produce seeds and, therefore, must be propagated by some method other than by seeds. This will be explained later. (Chapter VI.)

Flower Types.—A flower which is composed of the four sets of organs is said to be *complete* (Fig. 40), and a flower possessing both stamens and pistils, regardless of the presence or absence of calyx and corolla, is said to be *perfect.* (Fig. 40.) A flower in which the number of organs in each set is the same or a multiple of the same is *symmetrical.* (Figs. 42 and 43.)

If all of the organs of each set are the same size and shape it is *regular*. (Fig. 40.) The opposites of the above are: *incomplete, imperfect, unsymmetrical* and *irregular*. The apple, peach and cherry (Figs. 40 and 41) are complete and perfect; the lily (Figs. 42 and 51) is symmetrical and regular; the corn (Figs. 46 and 48) and castor oil plant are both incomplete and imperfect; the apple and peach unsymmetrical; the violet and bean (Fig. 47) irregular.

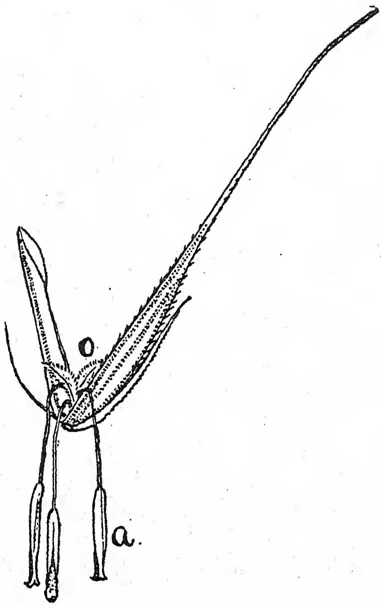


FIG. 45.—Single blossom of rye; a, stamen; o, pistil.

Imperfect Flowers.—Some plants bear two kinds of imperfect flowers, those with stamens which are known as *staminate flowers*, and those with pistils which are known as *pistillate flowers*. In some cases the two sets of flowers are so different in general appearance as to be readily distinguished while in other cases they are very much alike and cannot be distinguished except by a more careful examination. Plants which bear these two kinds of imperfect flowers are said to be *monœcious* (Figs. 46 and 48), *i.e.*, of one household. The common corn is a good example of a monœcious plant, the tassel being composed of staminate flowers while each grain with a single thread of silk is a pistil. Each mature grain of corn is a fruit produced from a single pistillate flower.

Other plants bear the staminate and pistillate flowers on different individuals and are known as *diœcious* (*i.e.*, of separate

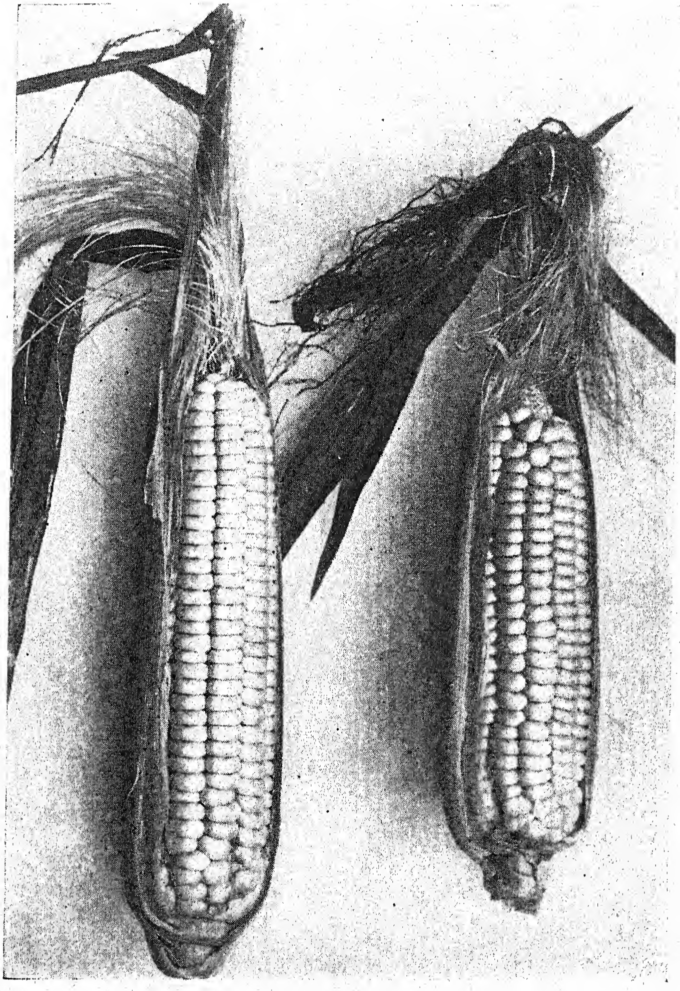


FIG. 46.—Two ears of Indian corn; *i.e.* the pistillate flower.

households). The mulberry, willow and poplar are excellent examples of diœcious plants. The fruits of these plants are always borne on the pistillate plants.

In the examination of a large number of plants we will find many interesting modifications of strictly monœcious and diœcious types. The Indian turnip or Jack-in-the-pulpit (Fig. 49) is usually diœcious, but many plants will be found which are monœcious. Some species of plants, of which the maples are good examples, both bear perfect and imperfect flowers, while individuals are frequently found which do not bear flowers of any kind.

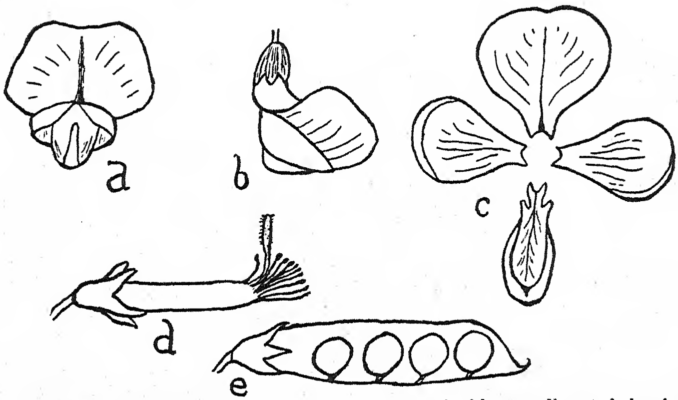


FIG. 47.—Legume blossom; a and b, the blossom; c, the blossom dissected showing the petals; d, the sepal, stamen and pistil; e, the mature seed pod.

Modified Calyx and Corolla.—Both the calyx and the corolla are frequently modified. The simplest modification is the union or partial union of the sepals or petals or both to form tubes. Flowers in which these unions occur are described as *gamo-sepalous* and *gamo-petalous* (Fig. 50), while those in which there is no union are described as *poly-petalous* and *poly-sepalous*. (Figs. 40, 42, 43 and 51.) The petals and sepals may also be modified to form spurs, as in the violet, or in many other ways. The calyx and corolla are borne on the receptacle, but in some cases the corolla appears to be attached to the calyx. We will find these numerous modifications of very great interest, and they are of very great importance in the life history of

FIG. 48.—The tassel or staminate flowers of the Indian corn.

the plant. This question will be taken up more fully on page 80.

Parts of the Stamens.—An ordinary *stamen* (Fig. 40) consists of two very distinct parts, the *filament* or stem, which corresponds to the petiole and midrib of a leaf, and the *anther,* at the tip, which corresponds to the blade rolled or modified so

as to form small sacs containing a delicate powder, known as *pollen.* The stamens also present different forms in the various plants. They are usually borne on the receptacles, but sometimes appear to be attached to other parts. They are frequently united into groups and in some plants in such a manner as to form a tube enclosing the pistil. The little pollen sacs have different methods of opening which may be readily seen with the hand lens and which will prove very interesting to the close observer. The pollen is very important. No two plants have exactly the same kind of pollen. It varies in size, shape and structure. The study of the pollen of various flowers under the microscope is very interesting. It is carried by wind and water, and sometimes by other means to the pistil, where it undergoes a growth which will be described later. (Chapter VI.)

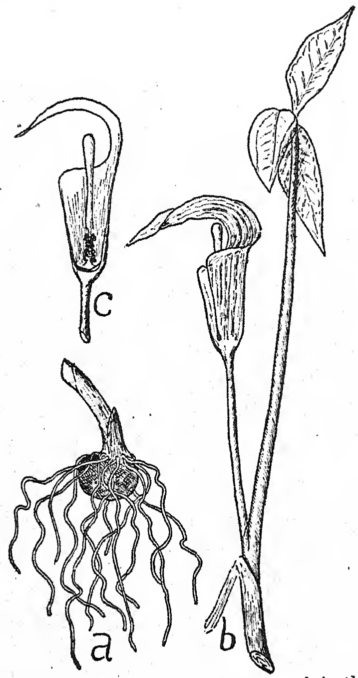


FIG. 49.—Indian turnip or Jack-in-the-pulpit; a, bulb; b, leaf and spathe; c, spathe open to show spadrix and flower near the base.

The Pistil.—There may be one or more pistils. (Fig. 40.) If one, it may represent one or it may represent many united leaves. Where there are two or more pistils, they may be entirely separate or they may be partly united. The pistil is composed of an ovary or basal part containing the *ovules,* which are to become seeds; a *style,* which varies in length in different plants; and a *stigma,* which is the only part of the plant not

covered with an epidermis or skin. The pistils are also subject to many modifications, but are always borne on the receptacle. However, if the other organs originate below the ovary, it is said to be *superior* (as in the peach flower), but if they originate above it, it is said to be *inferior* (as in the apple blossom).

The arrangement of the organs in the flower can be described by three terms: *hypogynous* (Fig. 44), the simplest form, in which the sepals, petals, and stamens arise from below

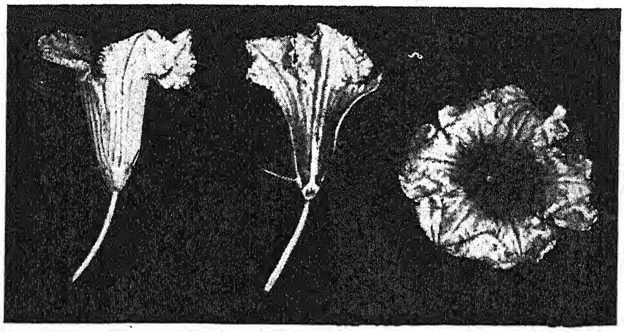


FIG. 50.—Squash blossoms. A gamopetalous flower.

the carpels; *perigynous* (Fig. 40), in which the receptacle is extended into a cup-like structure about the carpels and bearing the sepals, petals and stamens on its rim and frequently more or less united at their bases; and *epigynous,* in which this cup envelops the ovary, thus giving the true inferior ovary.

The modified leaves of which the pistil is composed are frequently called the carpels, and the point of attachment of the ovules is called the placentæ. The placentæ may be either *central* or *parietal* (*i.e.,* on the sides of the ovary). The number of carpels can usually be determined by cutting a cross section of the ovary and examining with a hand lens; the number of carpels being represented by the number of fibrous bundles which correspond to the midribs of the leaves of which the

pistil is composed. The number of carpels does not necessarily correspond with the number of chambers in the ovary. Of course, it will be readily recognized that the ovary eventually becomes the seed case of a dry fruit and that it is also an important factor in the formation of fleshy fruits.

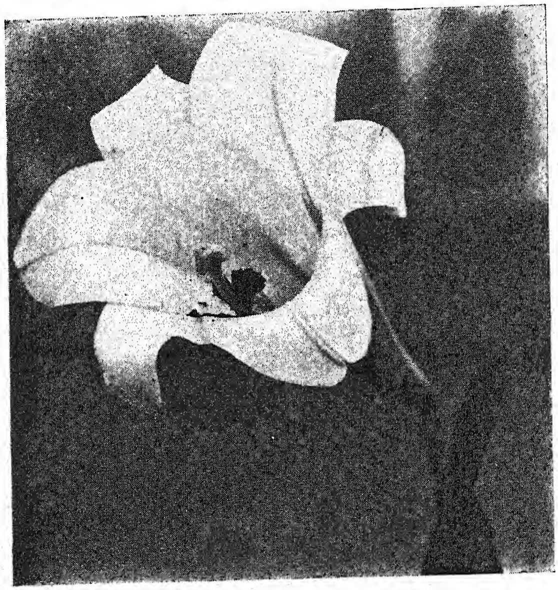


FIG. 51.—Lily blossom. A polypetalous flower.

Flower Clusters.—The arrangement of flowers on the stem is called the *inflorescence.* A few of the most common types of inflorescence are as follows: (1) The *raceme* (Fig. 52) in which a number of flowers are borne along a stem, the lower blooming first. The minute leaf which is usually at the base of each flower is called a bract. (2) The *corymb* is a raceme in which the pedicels, or little stems, of the lower flowers are elongated so that the flowers are practically on the same level.

(3) The *umbel* (Fig. 53) in which the pedicels arise from the same point and are practically the same length. (4) The *spike* (Figs. 54, 55 and 56) in which flowers are numerous, compact and sessile. (5) The *head* (Figs. 57 and 58), in which the main stem is shortened, giving rise to a cluster of flowers forming a more or less definite sphere. (6) The *spadix* (Fig. 49) in which the main stem is fleshy and the cluster of flowers enveloped in a leaf-like structure called a spathe. (7) The *catkin* in which the minute flowers are more or less compact, and the

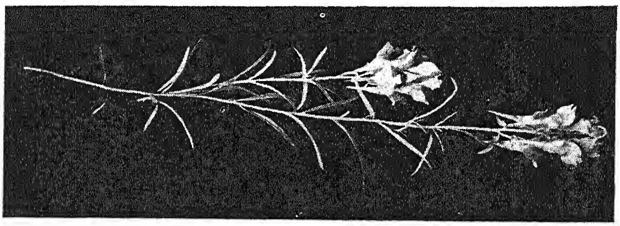


FIG. 52.—Toad flax blossoms, showing the open development of the blossoms.

entire raceme pendant. (8) The *cyme* which is similar to the raceme, but which differs from all of the preceding by having the apical flowers bloom before the lateral flowers. Finally, there are many special terms which are used for describing other forms of inflorescence, but which we will omit for the present.

CLASSIFICATION

Flower Types—When we stop to think about, or try to count and record the many plants with which we are familiar, although we may not know their names, we find that we have a task which is extremely difficult. But when we realize that we know only a few of the many hundreds of thousands of plants of different kinds which are distributed over the face of the earth, we understand that we must have some very definite system of classification or grouping by which we will

be enabled to locate and record them and designate those in which we are most interested. This system must be the same throughout the world and for people of all civilized languages. Several systems have been suggested, used and discontinued at various times during the centuries that mankind has studied plants. The one that we now use is known as the natural system and is, no doubt, better than any of the preceding. By this system, we try to group or classify plants by their blood relationships and not upon the superficial resemblances.

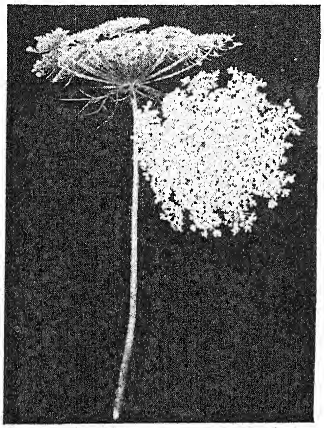


Fig. 53.—Wild carrot blossoms. The umbel type of inflorescence.

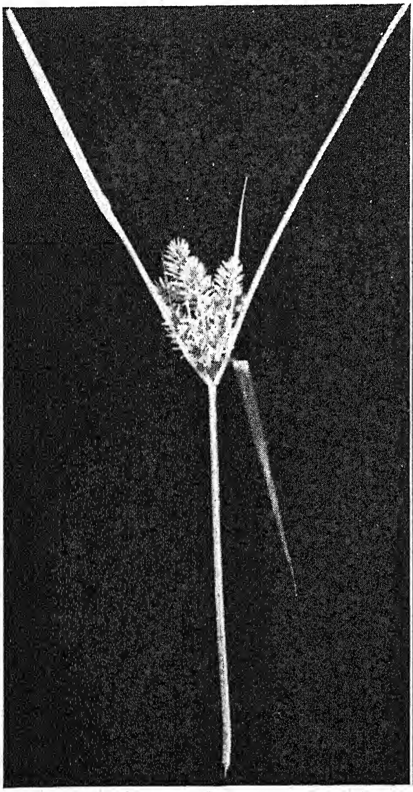
We readily recognize that apples, pears and quinces are very much alike. The foliage on the trees is almost identical, the flowers have corresponding parts in the same general arrangements, and if we cut the fruits we find that they have the same general characters.

Peaches, plums and cherries form another well-defined group; they also have flowers and fruits of the same character.

Now if we compare one of the two groups with the members of the other we find that the flowers of all are very similar except that in the ovaries and fruits of the two groups they are quite different. In the first group the ovaries are inferior and the fruit with a five-parted, papery seed chamber, while in the second group, the ovaries are superior and have the one stony seed chamber.

If we take the blackberries and the raspberries as representing a third group, we find flowers similar to the preceding but with masses of superior ovaries; and if we take the wild

rose as representing a fourth group, we again find flowers strikingly similar to these groups but with inferior ovaries that never have the development represented by the apple.



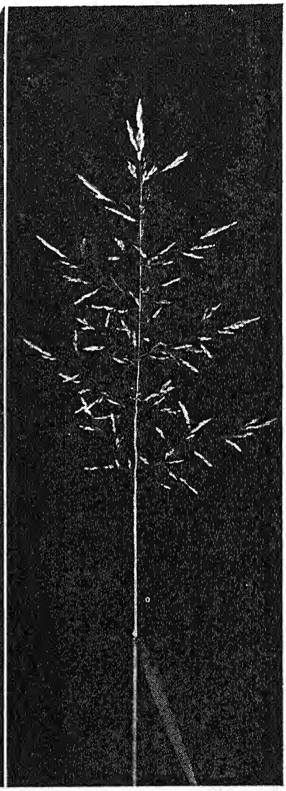


FIG. 54.—Sedge or spike type of inflorescence. FIG. 55.—Blue grass inflorescence.

Now, the very great resemblance in all these groups leads us to place them all in the one family, *Rosaceæ*.

But in the study of these characters we must make sure that the resemblances are real and not superficial. The fruits of the blackberry and mulberry are very similar in general appear-

ance, but when we go back to the flower and study them botanically, we find that they are quite different; the fruit of the former is composed of the many ripened ovaries of a single

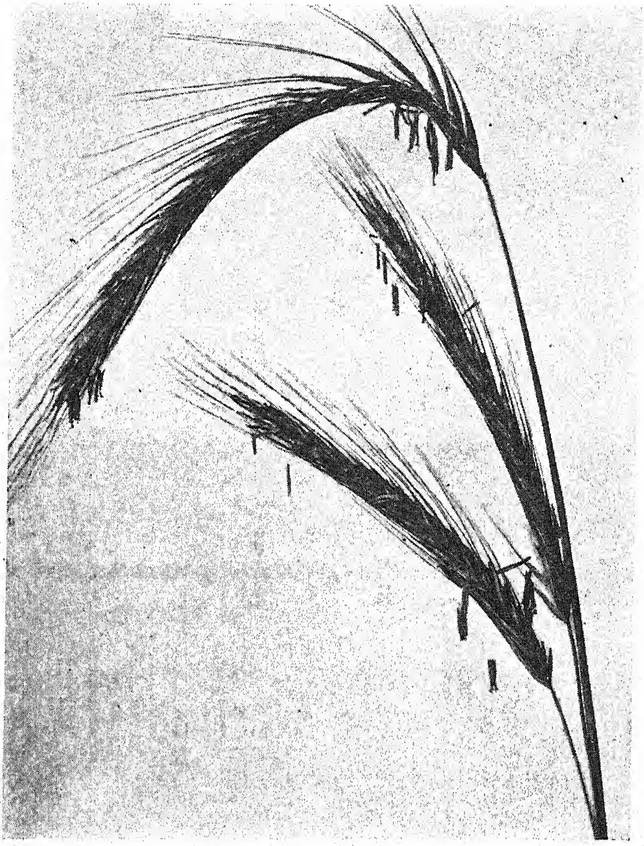


FIG. 56.—Rye inflorescence.

flower, while the fruit of the latter is composed of the ripened ovaries of a number of small flowers.

On the other hand, the potato, tomato, pepper and tobacco

may appear quite different, but an examination of the flowers shows them to be very similar and belonging to one family (*Solenaceæ*). The flowers of the potato, tomato and pepper are very similar; the flower of the tobacco is somewhat different,

Fig. 57.—Sunflower head. Composite type of inflorescence.

but has the same general characters; the cultivated potato has almost the power of producing fruit, but when the fruit is produced it is very similar to a small tomato; the fruit of the tomato is fleshy; the fruit of the pepper very similar but tending to become leathery; the fruit of the tobacco is of the same character but tending to become papery in character.

The Natural Classification endeavors to group plants in accordance with true botanical resemblances, and these groups are combined into larger, until we have the entire plant kingdom in four large groups. Thus far we have studied flowering plants only, but the plant kingdom includes many plants which do not produce flowers or seeds. The principal groups of the plant kingdom may be represented by the followig outline:

A. Cryptogams (Seedless plants)	1. Thallophytes	*a.* Algæ—mostly water plants. *b.* Fungi — plants without chlorophyll; moulds, mushrooms, etc.
	2. Bryophytes	*a.* Hepaticæ — Liverworts. *b.* Musci—Mosses.
	3. Pteridophytes	*a.* Ferns and related plants.
B. Phanerogams (Seed plants)	4. Spermatophytes	*a.* Gymnosperms — cone-bearing plants; pines, cedars, etc. *b.* Angiosperms — true flowering plants.

For the present we will not study the *Cryptogams* or the *Gymnosperms,* but will continue our studies on the *Angiosperms* or true flowering plants. We have already learned that this last group is sub-divided into *monocotyledonous* and *dicotyledonous* plants, and that in the former the embryo has but one cotyledon, while in the latter it has two. When we do not have the seed, or when it is too small for the determination of this point with ease, the classification may be determined by the following characteristics of the mature plant: The monocotyledonous plants usually have leaves with parallel veins and stems

with irregular arrangement of fibro-vascular bundles (*endogenous*); the dicotyledonous plants usually have leaves with net veins, and stems with the fibro-vascular bundles definitely arranged to form a circle (*exogenous*).

Both groups are sub-divided into orders, and these orders into families, these families into genera, and these genera into species. The *generic* and *specific* names constitute the scientific or Latin name of the plant. The classification and naming is the same in all civilized languages. The committing to memory of classifications and scientific names is wasted time and useless, unless we understand the relationship of plants and the basis for their groupings. However, a careful study of plants will enable the thorough and closely observing pupil to classify many plants to their families and even to their genera without the use of a manual. Students who are interested in the classification of plants should secure and use a manual suited to the locality in which they live.

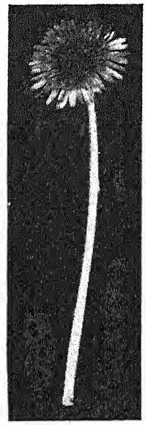


FIG. 58.—Dandelion head. Composite type of inflorescence.

EXERCISES WITH FLOWERS

1. **Plant Studies.**—The study should be associated with the plant as a whole, provided time and material will permit. The following points should be determined if possible:

(1) Is the plant monocotyledonous or dicotyledonous?
(2) Is it an herb, shrub, or tree?
(3) Under what conditions did it grow?
(4) Describe in brief the root, stem and leaf.
(5) Is the flower perfect or imperfect?
Is the flower complete or incomplete?
Is the flower regular or irregular?
Is the flower symmetrical or unsymmetrical?

(6) If imperfect, is it monœcious or diœcious?
(7) What is the type of inflorescence?
(8) Is the flower apetalous or complete?
(9) Is the flower poly- or gamo-sepalous?
(10) Is the flower poly- or gamo-petalous?
(11) Is the ovary superior or inferior?
(12) How many sepals, petals, stamens and pistils?
(13) To what are the different sets of organs attached?
(14) If unsymmetrical, describe the parts.
(15) Describe the stamens. How do they open?
(16) Describe the pistil or pistils. What type of placenta? How many ovules (estimated by cross and long sections)?
(17) If a single pistil, how many carpels and chambers?

2. **Plant Description.**—Having determined the preceding points a complete description of the plant and flower should be written. The pupil is now ready to use a manual for the determination of the family, genus and species. The family characters should be carefully noted and when another plant of the same family is studied, the pupil should try to determine the family without the use of a manual.

3. **Careful drawings and diagrams** should be made of all plants and flowers studied.

The following types are suggested for these exercises:

Monocotyledonous	*Dicotyledonous*	
Lily	Rose	Potato or tomato
Tulip	Apple or pear	Sunflower or daisy
Lily of the Valley	Peach, plum, cherry	Dandelion
Amarillus	Blackberry	Morning glory
Indian turnip	Pea or bean	Melon or gourd
Wheat	Bloodroot	Maple
Oats	Mustard	Elm
Corn	Buttercup	Oak
		Willow

QUESTIONS

1. What are the parts of the flower?
2. What constitutes the floral envelope?
3. What constitutes the essential organs?

4. What do you understand by complete, perfect, symmetrical and regular flowers? Give examples of each.

5. What is meant by apetalous, gamo-petalous and poly-petalous?

6. What is meant by monœcious and diœcious?

7. What is the difference between superior and inferior ovaries? Give examples of each.

8. Define carpel, placenta.

9. Give the different forms of inflorescence and examples of each.

CHAPTER VI

REPRODUCTION

Reproduction Without Seed.—We have already referred to some of the methods of reproduction in plants. We have learned that a bud is an undeveloped stem with its undeveloped leaves; and that the cuttings of many plants when placed in moist soil or in water will grow readily; that is, the buds expand, a root system is developed and a new plant possessing a complete set of organs like the parent is formed. In nature many plants, such as the willow, shed twigs which catch in the soil and grow. This growing of twigs explains the rapidity with which willows come into existence along water courses. Many grasses and other troublesome plants increase in number as a result of having the underground stems torn in pieces by farming tools, thus permitting each bud to form a new plant. We know that this power of buds to grow makes it possible to perpetuate many valuable varieties by cuttings, budding, and grafting. These methods are the common practices of florists, nurserymen, orchardists and others who wish to produce large numbers of plants of definite varieties.

Many plants are grown almost exclusively from the tubers or bulbs which we now recognize as forms of stems (Chapter IV), and many of these plants have partly or entirely lost their power to produce seeds. Plants which have lost this power to produce seeds must be grown entirely from bulbs, or cuttings, or by budding or grafting.

We know that, although roots do not generally produce buds, many plants are propagated by shoots developed from adventitious buds formed on the roots. The sweet potato

is a notable example of a root producing buds and young plants. And finally we know that even the leaves of some plants have the power to produce buds which will grow into plants. But this is not so strange as it may first appear, when we stop to consider that the ovules which develop into seeds are a part of the pistil which is a modified leaf. It is very evident that the preceding methods of reproduction by buds is very rapid and that a large number of new individuals like the parents can be produced in a very short time. It is known as the asexual or non-sexual method.

By Flowers and Seeds.—However, the most important, the most complicated, and the highest method of reproduction is by means of seeds which are the result of the *sexual* activities of the plant. In all the preceding methods of reproduction, each young plant has but one parent. But in reproduction by means of seeds each plant, with a few exceptions (Chapter V), has two parents. The stamens may be considered the male organs and the pistils the female organs, and the process of seed production may be briefly described as follows: Within the anthers are borne great numbers of pollen (Fig. 59) grains which are readily recognized as the powder which is so abundant in the large lilies and many other flowers. This pollen must be transferred to the stigma of the pistil of the same or another flower. (Fig. 60.) You will recall that the stigma is the only part of the plant that is without an epidermal covering. (Page 62.)

The transfer of the pollen is sometimes accomplished by some of the many insect visitors that are attracted by the honey or odor of the flower, or by humming birds, or in some cases by the wind. The transfer of the pollen is called *pollination,* and should not be confused with *fertilization.* Each pollen grain is a single cell which undergoes a growth resulting in the formation of a long, delicate tube which grows downward

through the style and eventually reaches the ovule. The tube enters the ovule usually through the micropyle (Chapter I), which persists and is plainly visible in many mature seeds. In the meantime, interesting changes are going on within the small ovule, which results in the formation of a minute chamber known as the *embryo sac.* (Fig. 61 *a.*) This sac contains eight minute cells, one of which is known as the *ovum* or *egg.*

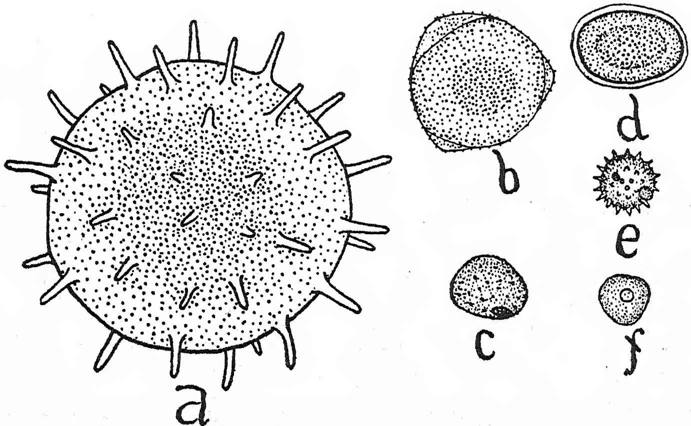


FIG. 59.—Types of pollen grain.

The tip of the pollen tube finally reaches this egg cell and a certain nucleus from the tube unites with the nucleus of the egg. This is the process of true *fertilization,* and this fertilized egg now develops into an embryo or young plant (Fig. 61 *b*) surrounded by a supply of rich food for its future nourishment. This embryo, together with its food supply and coverings, constitutes the seed. (Chapter V.) The parts involved in this process are so small that it is impossible to see them without using a compound microscope, and the study of this delicate and complicated process must necessarily be reserved for the more advanced students of botany.

No two plants in nature are ever exactly alike and, therefore, if the pollen of one plant falls on the pistil of a slightly

different plant of the same or a closely related species or variety, the new plants should possess some characters of both parents, This gives a basis for work in the production of new varieties of plants. (Chapter XV.)

Differences in Structures of Seeds.—There are some facts concerning the structure of the seed which we have already learned, but which we should now recall in the light of these new facts. (Chapter VII.) The young plant or embryo consists of a very short stem on one end of which is a root tip; and on the other end a plumule, or bud, and one or two cotyledons or primary leaves. It is a complete plant possessing the three essential parts: *root, stem,* and *leaf.* We will recall that the seeds of corn and castor oil plants contained embryos surrounded by an abundant food supply for their nourishment during the period of germination and before they had become firmly established as independent plants. We will also recall that in the bean we found a much larger embryo without the surrounding food supply. In this case the food for the early growth of the young plant was in the cotyledons.

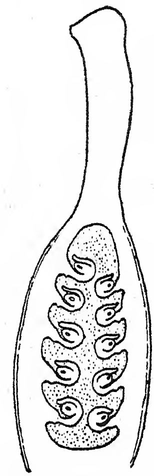


FIG. 60.—Diagrammatic longitudinal section of ovary showing developing ovules.

The seeds of corn and castor oil plant matured very early when the embryos were small, but with a good supply of stored food for the growth of the embryo during germination. The seed of the bean matured much later, the embryo having absorbed the surrounding food supply and stored it in the cotyledons previous to maturity. In the corn, the single cotyledon is an organ which serves for the absorption of the food supply; in the castor oil plant the cotyledons serve first as organs of absorption and later as the primary leaves; in the bean they serve for the storage of the food supply and as primary leaves.

The examination of the seed of a large number of different kinds of plants will show great variation in the relative sizes of the embryos and the amount of the food supply, and will suggest many germination tests and growth experiments.

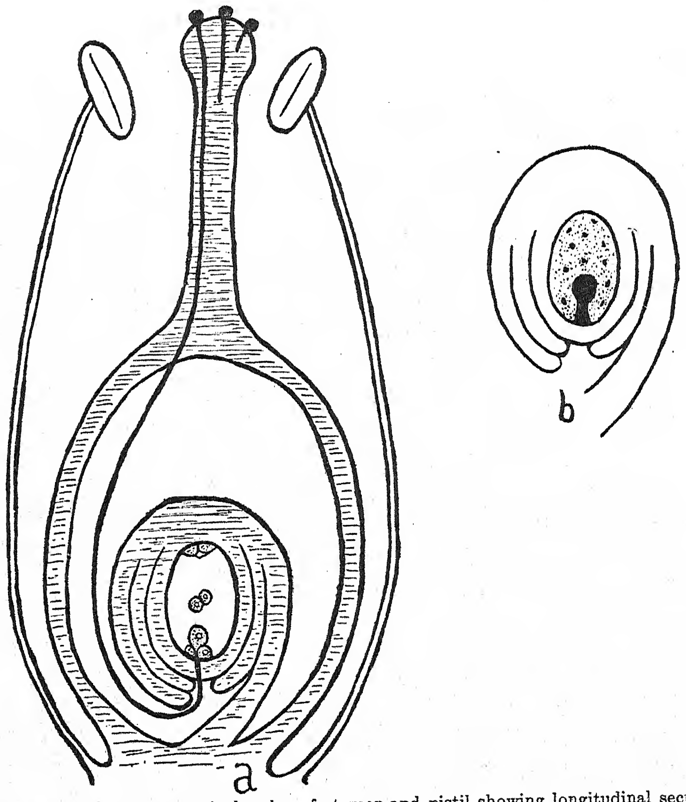


Fig. 61.—a, diagrammatic drawing of stamen and pistil showing longitudinal section of ovule. The pollen tube is entering through the micropyle; b, longitudinal diagrammatic section of ovule showing the formation of the embryo.

Advantages of the Seed Method.—It is very evident that sexual reproduction is higher and more complicated than nonsexual reproduction, but let us see if it is of any advantage. It is necessarily much slower than reproduction by buds, but the

dry seeds of a plant can undoubtedly resist greater extremes and longer duration of heat, cold and drouth than buds and can be carried to much greater distances by natural means and by man. Many believe that sexual reproduction gives the plants much more vigor than non-sexual reproduction. This belief seems to be supported by the fact that when some varieties of plants are grown continuously from cuttings, tubers or bulbs, they tend to lose their original varietal characters and vitality. Sexual reproduction, owing to the fact that the two parents are never exactly the same, tends to cause variations in plants, and results in new varieties. This tendency to produce variations is greatly increased by cross breeding different varieties and has given rise to some of our most valuable fruits, vegetables and ornamentals. (Page 148.) The transfer of the pollen from the stamens to the stigma is known as *pollination* and should not be confused with *fertilization*. (Page 76.).

Pollen may be carried by the wind, and some of our most valuable plants depend entirely upon the wind for pollination. The corn and other grains and grasses belong to this class. The tassel of the corn is a mass of small staminate flowers, while each thread of the silk represents a pistil with a single grain of corn for its ovary. During the blooming season there is a rain of pollen grains, some of which fall upon the silk. Of course, this is in a sense very wasteful for the number of pollen grains which are lost is *infinitely* greater than the number which fall upon the silk (*i. e.,* pistils).

Insect Pollination.—The great majority of our flowering plants are pollinated through the agency of insects, which visit the flower primarily to collect the nectar and pollen. Many insects use the nectar immediately for food, but the bees take it into their bodies where it undergoes chemical changes by which it is transformed into honey and then stored up for future use. Many insects are doubtless attracted by the odors of flowers and some few may be attracted by the color, although

we should remember that it is extremely doubtful if insects can distinguish shape, size or color for any considerable distance.

Interesting modifications of their parts are found in many flowers. These facilitate pollination by means of insects, and some flowers are so specialized that certain insects are necessary for this work. Among the simplest of these modifications is the long tubular corolla of the morning glories and honeysuckles which make it necessary that their visitors have long beaks or mouth parts by which they can reach the nectar glands at the bottom. The tubular corolla of the red clover is such that it is imperfectly pollinated except by the bumble bee and, therefore, it is practically impossible to grow red clover seed without these insects. The barberry, and some other plants, have stamens of such character that when touched by the insect they serve as springs, striking the anthers against its body. The milkweed and other plants are so constructed that masses of pollen may cling to the body of the insect and be carried from flower to flower, losing some pollen with each visit. Beans, peas, and similar flowers have peculiarly shaped corollas which conceal the essential organs, but when the insect settles upon them these parts are exposed and the lower surface of the body brought in direct contact with them. A thorough discussion of the devices for facilitating the pollination by means of insect visitors would require a large volume and then be incomplete, but it is a subject in which any close observer can learn something previously unknown, something not in the books.

Cross Pollination.—It will be readily seen that sexual pollination is usually accomplished by the pollen of one flower on the stigma of another flower of the same or a different plant. This is known as *cross pollination* and, of course, results in cross fertilization which, as previously stated, is believed, in many cases, to give increased vigor to the new generation of plants. If this is true, we are certainly justified in expecting to find some modifications in nature which prevent *self-pollin-*

ation. If we examine flowers carefully we will find some in which the stamens and pistils mature at different times and, therefore, it is impossible for the flower to be pollinated by its own pollen. Of course, the flowers do not open at the same time and pollen of some flowers will mature at just the right time to be transferred to, and grown on, the stigma of others. Sometimes the flowers will be pollinated from other flowers of the same plant and sometimes by flowers of different plants. In some plants we can see the effects of this cross pollination in the seeds, as in the case where corn of one color has been pollinated by corn of another, resulting in the speckled or mixed ears. But in most plants we do not see the results of cross pollination until we grow the new plants. Cross pollination is accomplished in various ways. Some plants have two kinds of tubular flowers, some with short stamens and long pistils, and others long stamens and short pistils. The insect visiting the first flower gets pollen on the front part of its body; visiting the latter it leaves some of the pollen on the short pistil and gets a load of pollen on the back part of its body. Therefore, it is practically impossible for the flower to be pollinated with its own pollen. Some plants, especially cultivated varieties, have impotent pollen and, therefore, cannot be pollinated with their own pollen or with pollen from plants of the same variety. Many apple, pear and plum growers mix their varieties in the orchard so as to insure pollination and thus get the stimulating effect of fertilization and secure a richer harvest. In some cases, growers may even set a few trees of an inferior variety in order to secure satisfactory cross pollination of the desirable varieties. In some plants, such as the common banana, the pollen is useless and the plants no longer produce seeds.

Diœcious plants (Chapter V) are necessarily cross pollinated, and many savage and half-civilized races learned, many centuries ago, the necessity of growing the staminate as well

6

as the pistillate trees, although they had no explanation for this phenomenon of nature.

Self-Pollination.—However, the flowers of some plants are very generally self-pollinated. Wheat belongs to this group or class.

Buds That Never Open.—The buds of some flowers never open, making cross pollination impossible. Such flowers are called *cleistogamous.* Some species of violets produce inconspicuous cleistogamous buds under the leaf-mold, these buds producing abundant seeds, while the showy flowers of these species are usually sterile.

EXERCISES IN POLLINATION

1. **Carriers of Pollen.**—Observe flowers and note the insects which visit them. Are the different species of flowers visited by the same species of insects? Do the insects exercise a choice in visiting flowers?

2. **Examine pollen** of a number of flowers under the microscope. Make drawings.

3. **Pollen Growth in Sugar Solution.**—Make a solution by boiling one part of sugar in ten of water. Put a spoonful into each of several watch glasses. Mix the pollen of several flowers into them and keep covered. Examine a drop of the fluid with pollen under the miscroscope from time to time and note the germination.

QUESTIONS

1. How do you account for the rapid increase in numbers of willows and similar plants along water courses?
2. Can other plants be produced in a similar manner?
3. How do we make use of this power of reproduction in the growing plant?
4. How are many grasses and other pests frequently propagated?
5. Give a list of plants that grow from bulbs.
6. Give a list of plants that grow from tubers.
7. Give a list of plants that are seldom or never grown from seeds. How are they grown?
8. Do roots produce buds? Give some exceptions.
9. Explain pollination.
10. Explain fertilization.
11. Explain cross pollination.
12. Explain self-pollination.
13. Explain cleistogamous seed production.

CHAPTER VII

FRUITS AND SEEDS

We make use of plants in a great many ways, but the most important way is as food for the sustenance of life of man and beast. Among the most important parts of the plants used for this purpose are the *seeds* and *fruits.* However, these terms (*fruit* and *seed*) are very indefinite and should be used with care. Fruits and vegetables are frequently confused; the tomato is usually spoken of as a vegetable, although the edible part does not differ materially from many true berry fruits. Botanically, a *fruit is the ripened ovary, or the ripened ovary with such other parts as may be united to it.* However, some fruits, such as the banana and the navel orange, have lost the power to produce seeds and the fruit consists of only the ovary. They are known as seedless fruits, and these plants must be propagated by some of the non-sexual methods previously referred to. (Chapter VI.) Although we usually think of fruits as being fleshy structures, the cotton boll, a gourd, a pepper pod, or a bean pod are fruits as truly as is the peach or apple. *The seed is the mature ovule with its enclosed embryo,* or as we may have learned, *the embryo with food supply and coverings.* The final result of plant energy is the production of its kind and the distributing of its offsprings as far as possible. Each species of plant, if uncontrolled by climate, water, soil, animals and other plants would eventually tend to occupy the entire earth. But many plants cannot spread beyond a certain limit, because of the extremes of the climate; others are checked for want of suitable soil; others by bodies of water or desert plains; and still others by coming into competition with other plants which are stronger and crowd them out. Man has taken advan-

tage of this tendency of plants to reproduce themselves and to vary their characters, and has selected those which are the best suited to his purposes, and has protected and cultivated them. By his intelligent management he has increased their value to himself. (Chapter XV.)

For convenience we will classify fruits as follows:

Fleshy	Drupe	Simple drupe
		Aggregate
		Multiple
	Pome	
	Berry	
	Accessory	
Dry	Dehiscent	Pod or capsule
		Legume
	Indehiscent	Achens
		Caryopsis
		Samara or key
		Nut

The drupe or stone fruit has the seed surrounded by a strong, or hard, stony growth (endocarp) which is, in turn, surrounded by a fleshy growth (exocarp). The stony and fleshy growths constitute the ovary. The peach (Fig. 62), plum and cherry are of this type, and each fruit is a single or simple ovary derived from a single flower. (Page 55.) There are several modifications of the simple drupe which are given special names, but the differences are superficial. They are:

(a) **The aggregate fruit** which consists of a number of ripened, fleshy pistils derived from a single flower. The blackberry and raspberry are excellent types.

(*b*) **The multiple fruit** which consists of a number of small single pistils each derived from a single flower. The mulberry is a type. Although the blackberry and mulberry fruits show

a very striking superficial resemblance, they are radically different; the former representing a single, rather large flower with many pistils, and the latter a number of very small flowers, each having a single pistil. None of the above are true berries from the botanical viewpoint, but the name is so closely asso-

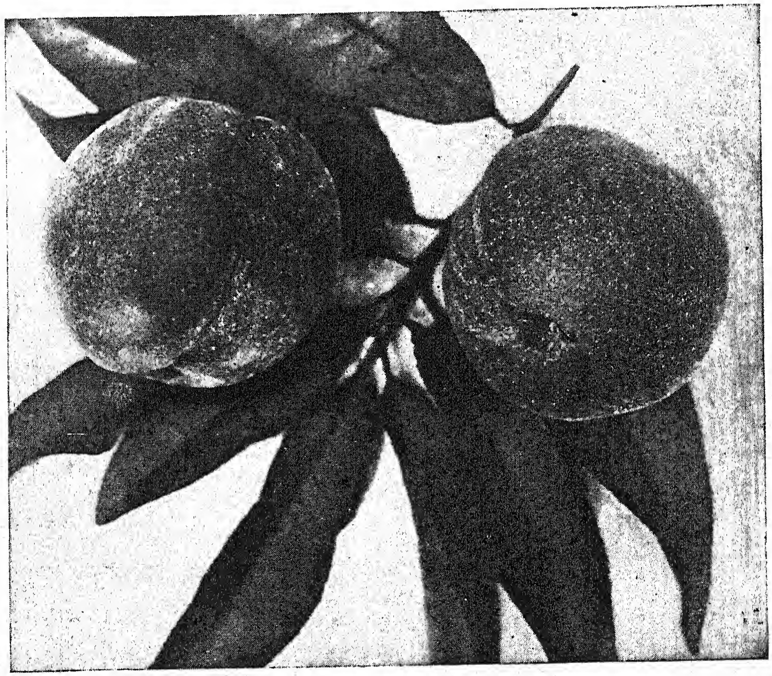


FIG. 62.—The peach, the drupe type of fruit.

ciated with them that it is practically impossible to make a change.

The pome is a fruit in which the ovary, or ovaries, the calyx and receptacle are united, both becoming fleshy. The tips of the sepals persist at the blossom end of the fruit and the

endocarp develops as a papery core. The apple (Fig. 63), pear and quince are typical of this group.

The true berry is a more or less leathery structure enclosing a mass of seeds. It may consist of the ovary only, or of the ovary enclosed in the calyx. Many plants belonging to a great diversity of families produce fruits of this type. Among the

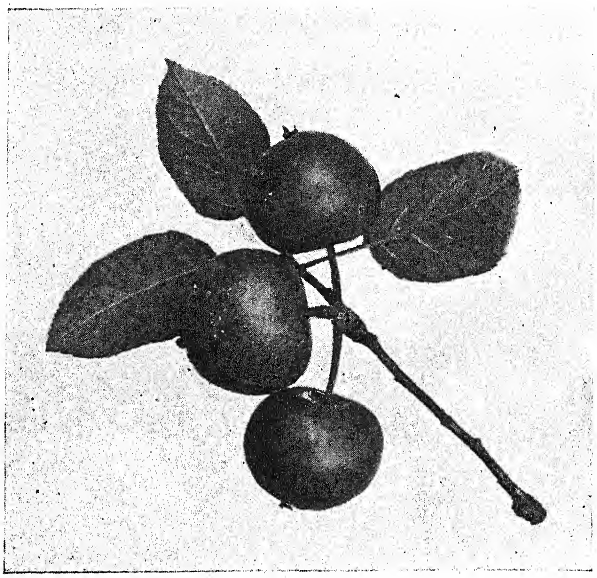


FIG. 63.—The apple, the pome type of fruit.

most important are the gooseberry, huckleberry, cranberry, grape, orange, melon and cucumber. However, melons, cucumbers and gourds and other fruits belonging to the family *Cucurbitaceæ* are frequently given a special name of "pepo."

The accessory fruit is the fleshy receptacle of a single flower covered with achenes which are usually called seeds; the strawberry belongs to this type.

The dry fruits are those in which the ovaries develop into dry pods. If this pod opens and releases the seeds it is *dehiscent*

(Fig. 64, *a*), but if it does not open until burst by the germinating seed, it is *indehiscent.* (Fig. 64, *b.*)

The term pod or capsule will apply to any of the dehiscent fruits, regardless of the number of carpels involved in its formation. The term *legume* applies to those peculiar elongated pods (Fig. 64, *a*) of the *leguminoseæ* or pea family, each of which represents a single capsule of two valves and a single placentæ.

The indehiscent fruits are:

(a) **The achene,** a small, dry, one-seeded pod representing one or more carpels. (Fig. 64, *b.*)

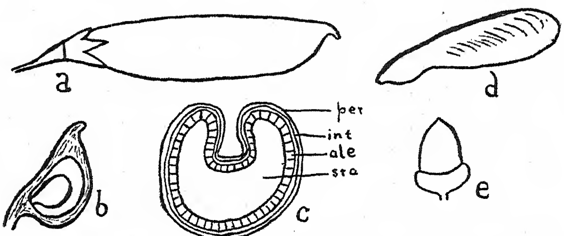


FIG. 64.—a, legume or dehiscent pod; b, an achene or indehiscent pod cut so as to show the enclosed seed; c, caryopsis or grain showing the pericarp or ovary, the integument or seed coat, the aleurone cells and the starch area; d, samara or key fruit; e, acorn or nut type.

(b) **The caryopsis or grain** in which the pod or ovary is united to the seed. (Fig. 64, *c.*)

(c) **The samara or key** in which the pod is developed into a thin flat wing. (Fig. 64, *d.*)

(d) **The nut** is a single seed in which the ovary is developed into a hard, bone-like or horn-like covering.

There are several types of nuts, such as the acorn (Fig. 64, *e*) which is a cup formed of involucral leaves; the *hazelnut, chestnut,* and *beechnut,* in which the nuts are enclosed in a pod also formed of involucral leaves; the *hickory nut* inclosed in a shuck, probably composed partly of calyx and partly of involucral leaves, which tend to split when dry. The *walnut* is of the same type as the hickory nut, but does not tend to split; it is some-

what fleshy and resembles the drupes, but the fleshy part is of an entirely different origin from that of the true drupes.

Fig Type.—There are some fruits which are difficult to classify in any of the preceding groups and must be distinguished by special names. Among the most important is the *synconium* or *fig* fruit which is derived from an enlarged, soft, hollow stem enclosing a large number of very small flowers which are never exposed. Many people believe the fig produces fruit without blooming, but this is not true.

Seed Distribution.—If seeds are to fulfill their place in nature they must be distributed over a considerable range of country. If they are all dropped within the immediate vicinity of the parent plant, the new plants will be too crowded, the weaker cannot survive, and the vigor of both parent and offspring will be impaired. Seeds are mostly carried by wind and water, by animals and by man. It is very evident to the most casual observer that of the enormous quantities of seeds produced by a single plant, very few can ever serve their primary purpose in nature, that of producing new plants. The majority will be eaten by animals, or will fall in unfavorable places where they cannot germinate, while many of those that do germinate will never grow to maturity. (Fig. 65.)

Carried by Water.—It is very easy to understand how seeds can be carried from place to place by water. Those that are buoyant will be carried along by streams, or float over the surfaces of lakes. Those that will not float may be carried along in the mud and debris. Heavy rainfall will carry many seeds for considerable distances and will frequently cover them with earth. Seeds that float are frequently propelled by wind and carried for long distances over lakes and other large bodies of water. Seeds from plants growing near the salt water will frequently be carried for long distances by means of water and wind and find a resting place on other shores. Of course, it is

important that seeds, which are carried in this manner, shall be of such character as not to be easily injured by long submergence in water, and this is especially true of those seeds which are carried by salt water. The cocoanut is a striking example of a large floating seed which frequently is carried on the salt water. The vegetation of the volcanic and coral

FIG. 65.—Devices for seed distribution.

islands of the sea frequently owes its origin to seeds of this type.

Resistance to Heat, Cold and Dryness.—The seeds of many plants are also resistant to extreme drying and to extreme heat and cold. The seeds of some plants will lie in the soil for years waiting until the conditions are favorable for their germination, while the seeds of other plants will perish in a few weeks or months, even when kept under the most favorable conditions.

Carried by Wind.—We have all observed the dispersal of seeds by means of the wind. Of course, strong air currents will carry light seeds for great distances, but many seeds have special structures which are very important in this work. The maple, ash and elm have membranous wings, or outgrowths by which the wind carries them. These outgrowths are a part of the ovary. The dandelion, lettuce, thistle and many other plants have seeds which are enclosed in the ovary (*achenes*), on which is developed a downy outgrowth serving as an air float, a sort of balloon or parachute. The seeds of the milkweed bear a superficial resemblance to those of the dandelion, but are quite different. You will recall that the dandelion is an indehiscent fruit, while the milkweed is dehiscent. The outgrowth on the former is from the ovary; on the latter from the seed coat. Some plants, especially weeds, of which the tumble weed is the most striking example, will break loose and be carried by the wind for great distances, distributing their seeds as they travel.

Carried by Man and Animals.—The lower animals are the involuntary carriers of many seeds, and man, the highest of the animals, is both an involuntary and a voluntary carrier. The seeds of many fruits will pass through the alimentary canal of animals unharmed and will grow if dropped in suitable places. Squirrels and other animals bury nuts and other seeds which grow; while birds accidentally drop the seeds of cherries, berries and other fruits, here and there. Burs and many other seeds have spines or hooks by which they cling to animals. Man carries many seeds in feed and bedding for himself and live stock, in packing materials, and in grain for various agricultural and commercial purposes. The shipping of grain and grass seeds from country to country has been the means of introducing many of our most troublesome weeds.

Seeds Thrown.—Many plants have peculiar devices by which seeds are thrown for considerable distances. The touch-

me-not is an excellent illustration of this last method. The pod splits suddenly and the parts curl with such force as to throw the seeds out.

EXERCISES CONCERNING FRUITS AND SEEDS

1. **The Peach.**—Examine the fruit of the peach. What part of the flower is involved in its make-up? How many carpels does it represent? Note the fleshy *exocarp,* the hard *endocarp* and the *seed.*

2. **Blackberry.**—Examine the fruits of the blackberry or dewberry What part of the flower? How many carpels? Where are the exo- and endocarps?

3. Compare the fruits and tell how the blackberry differs from the raspberry.

4. Compare the fruits and state how the strawberry differs from the blackberry.

5. Compare the fruits and state how the mulberry differs from the blackberry.

6. **Apple.**—Examine the fruit of the apple or pear. What parts of the flower are involved in its make-up? How many pistils and carpels does it represent? How does the endocarp differ from that of the peach?

7. **Gooseberry.**—Examine the fruit of the gooseberry. What parts of the flower are involved in its make-up? How many pistils and carpels? What is the dry part on the tip?

8. **Melon, Orange** and **Tomato.** — Cut a melon or cucumber, an orange and a tomato in cross-section. Study in the same manner as the gooseberry.

9. **Seedless Fruits.**—Cut a navel orange and a banana in cross-section and study in the same manner. How do they differ?

10. **True Pods.**—Examine the pod of a bean or pea or similar dry fruit. How many pistils? How many carpels? Where are the seeds attached?

11. Examine as many other forms of pods as possible and answer the same questions.

12. **Winged Fruits.**—Study the seeds of the maple, dandelion, etc., for methods of distribution.

13. Study the seeds of the milkweed and compare with the dandelion.

14. **Burs.**—Study burs, stick-tights and other seeds for special devices for distribution.

15. **Explosive pods** such as the touch-me-not and witch hazel should be collected. Note their explosive power.

16. **Examine bladdery seeds** and ovaries of such plants as may be available.

QUESTIONS

1. What is a fruit?
2. What is a seed?
3. Give the different types of fruits.
4. Define each.
5. Give examples of each.
6. Give different methods of seed distribution and examples of each.

CHAPTER VIII

ANATOMY OF STEMS, ROOTS, AND LEAVES

We have learned that stems are composed of strands of woody, fibrous material embedded in a softer substance or pith, and that this entire structure is enclosed in a water-proof sheath of epidermis or bark. We have also learned that the arrangement of these strands of fibrous material, which are known as fibro-vascular bundles, is different in the monocotyledonous and dicotyledonous stems. In the former (Fig. 66) they are distributed throughout the stem except in those plants in which the stem is hollow, while in the latter they are arranged in a circle. (Fig. 67.) This difference in the arrangement of the mono- and dicotyledonous stems enables us readily to recognize these two groups of plants. (Chapter III.)

Cellular Structure.—If we can examine cross and longitudinal sections of a monocotyledonous stem with a microscope, we will find that the pithy part of the stem is composed of large, thin-walled cells. (Fig. 68.) We have previously referred to cells, but have not given an explanation of them. All parts of all plants are made up of cells of which this is the simplest type. The cell is the unit of the plant structure, the same as a brick or a stone may be the unit of a building. The name "cell" was given by the students of botany, soon after the invention of the microscope, who saw the plant as a structure composed of many minute, apparently empty boxes or cells. Later students learned that these cells when young and active contained a substance which we now call *protoplasm* (Fig. 69), and still later students learned that protoplasm might exist without being enclosed in a cell-wall. Therefore, the definition of

a cell was protoplasm which may be either naked or enclosed in a cell-wall, or a small microscopic chamber from which the protoplasm has been withdrawn.

The protoplasm is an albuminous substance more nearly like the white of an egg than any other substance with which we can compare it. It is that part of the plant in which the life is said to exist, and, so far as we know, is not different from the protoplasm of the animal cell. In its active condition, it is

FIG. 66

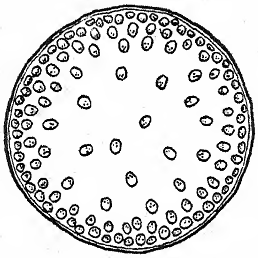


FIG. 67

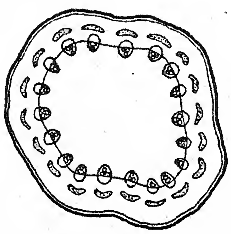


FIG. 68

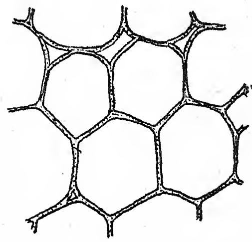


FIG. 66.—Cross-section of monocotyledonous stem showing arrangement of the fibro-vascular bundles.
FIG. 67.—Cross-section of dicotyledonous stem showing arrangement of fibro-vascular bundle.
FIG. 68.—Parenchyma cells.

very sensitive to change of humidity, temperature, and to poisonous substances. The active growing cells of the plant are rich in protoplasm, but many cells which persist throughout the entire life of the plant die and lose their protoplasm. In fact, the great bulk of the cells of most of our higher plants is dead.

The cell can be studied to the best advantage in some of the water plants, especially the algæ, which will be studied later. If we examine a very small amount of one of these plants known as *Spirogyra* under the microscope, we find that it is made up of a single row of elongated cells placed end to end. These cells appear to be rectangular, but they are cylindrical tubes closed at both ends. We very readily recognize the cell-wall and the chlorophyll, which is in a body known as the chromatophore.

If we examine the cells of other plants, we find that these chromatophores vary greatly in size and shape. The other parts of the cell are not so easily recognized. But if we will keep some of the algæ in alcohol for a few hours the chlorophyll will be partly or entirely removed so that we can recognize the very delicate layer of protoplasm lying next to the cell-wall and also delicate strands extending across the cell. This will be greatly aided by treating the algæ with eosin or some other coloring matter which will stain the protoplasm. In this plant, the protoplasm does not completely fill the cell, but there are large spaces which are filled with water or air and known as vacuoles. We will also be able to recognize the nucleus which is a very important part of the cell.

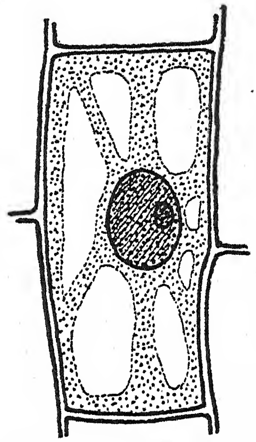


FIG. 69.—A typical plant cell showing protoplasm.

The nucleus is protoplasmic in character and very complicated in structure. It is present in nearly all living cells, and when the cell divides the nucleus also divides, one part going into each new cell. In a few plants, the cells are multinuclear, and when they divide some nuclei are found in each new cell.

Cells also contain many compounds. The most prominent is the starch, which can be readily recognized by examining a very thin section of potato or apple under the microscope. If we treat this section with iodine, the starch grain will turn blue. The starch grains of different plants differ in size and form; this fact enables the microscopist to decide on amount and character of many adulterations of foods and drugs. The cells also contain sugar, fats, oils and other compounds which will be discussed later. (Chapter IX.)

As the plant grows the cells undergo many changes and modifications. These variations are much more pronounced in the

higher or flowering plants than in the lower forms. Some cells have thin walls and contain a great deal of food materials which make them valuable foods for man and other animals. Some are fibrous in character and have thick walls which make them

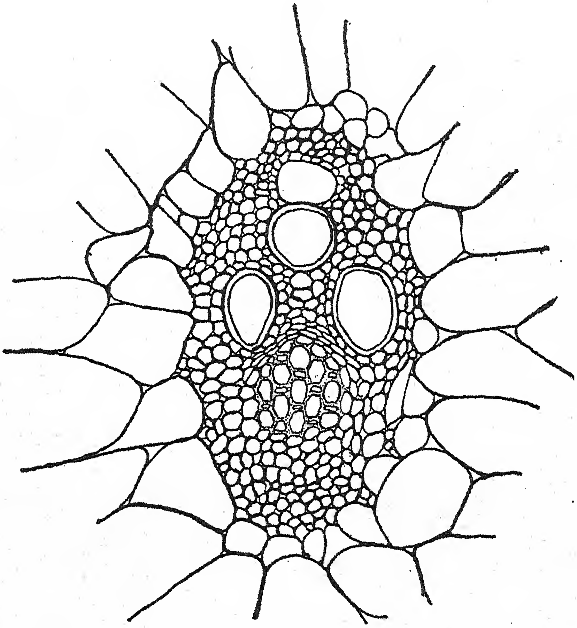


FIG. 70.—Cross-section of fibro-vascular bundle from corn stem.

useful in many industries. We will give a brief discussion of these different types of cells.

Parenchyma.—The cells of pith are large, somewhat variable in size, thin-walled, more or less spherical in shape and usually show irregular spaces between them. They are known as parenchyma or soft cells. (Fig. 68.)

The great majority of the cells of fruits, grains and other edible parts of plants are made up of parenchyma cells. Their

value as food depends on the size of the cells, the thinness of the cell-walls, the amount and digestible character of the food (carbohydrates, hydrocarbons, proteids; Chapter IX) which they contain, and the absence of poisonous or injurious compounds.

Each fibro-vascular bundle is made up of a variety of cells. In the young bundle of the monocotyledonous stem (Fig. 70) is a small group of cells known as the *cambium*. They have the

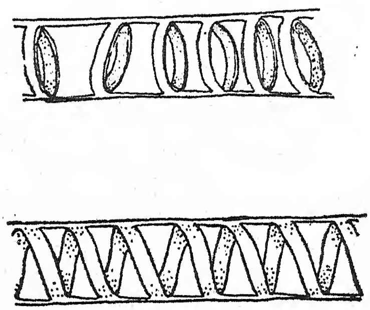


FIG. 71.—Tracheary tissue.

power of rapid growth and division and are primarily responsible for the increase in diameter of the monocotyledon stem. After a comparatively short time they lose the power of division and this checks the increase in diameter of the stem. On one side of the bundle will be a mixture of large and small cells constituting the *woody part*. Some of these cells have peculiar thickenings of the cell-walls forming rings, spirals, pits, etc. They are known as tracheids and tracheary cells. (Fig. 71.) On the opposite side of the bundle is a group of small, thick-walled cells constituting the fibre or bast. (Fig. 72.) There are other types of cells which will be described later. A monocotyledonous stem increases in diameter for a limited time only, partly by the increase in the size of the fibro-vascular bundles

and partly by the increase in number of bundles. The hard outer covering of the corn and similar plants is composed of these fibro-vascular bundles.

The dicotyledonous stem has bundles made up of the same kind of cells which are arranged very differently. The outer part of the bundle contains the bast; the inner, the woody cells; and between the two groups lies the cambium which persists throughout the entire life of the plant. The cells of the cam-

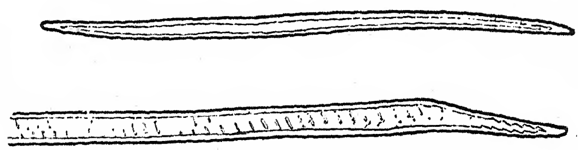


FIG. 72.—Fibrous tissue; bast and wood cells.

bium form a continuous layer of living, growing cells. These cells divide repeatedly cutting off inner layers which go to form layers of wood and outer layers which eventually help to form the outer parts of the stem. All the other types of cells are derived from these cambium cells. Among the bast cells are the peculiar *sieve cells* (Fig. 73) or tubes, so called because of the peculiarly perforated cross walls. On the opposite side of the cambium are a number of cells and tubes which have peculiar thickenings on the inside of the walls. If the cells are short, more or less tapering at the ends and with numerous pits in the walls, they are known as *tracheids,* but if they are elongated into tubes in which the wall thickenings take the form of spirals, rings, pits, etc., they are known as *tracheary tissue.* (Fig. 71.) This term is also used to include the tracheids. This tracheary tissue is surrounded by long *fibrous* or *wood* cells. (Fig. 72.) The outer part of the bundle containing the sieve and bast cells is called the *phloem* region; the inner part containing the tracheary and wood fibre is called the *xylem* region.

In the centre of the stem is the pithy *stele* composed of parenchyma cells. The fibro-vascular bundles are also separated by masses of thin-walled cells called the *medullary rays* (Fig. 74), and the entire structure is enclosed in an epidermal mass of cells known as the bark. In soft stems of the herbaceous plants, geranium, etc., the bundles are separated by thick medullary rays while in hard, woody stems of the tree, the rays are very thin. In the stems or trunks of young trees, the bundles are

Fig. 73

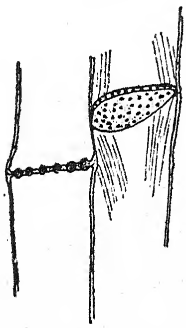


Fig. 74

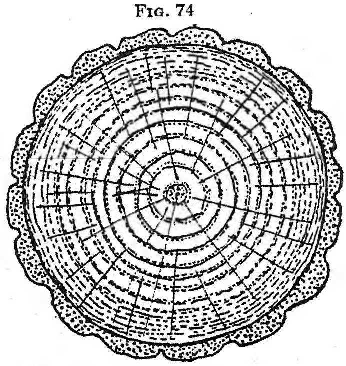


Fig. 73.—Sieve tissue.
Fig. 74.—Cross section of dicotyledonous woody stem, showing annual rings, medullary rays and bark.

few and the rays thick, but the number of bundles increases and the rays become thinner and thinner with age. If we cut across a large stem, *i.e.,* the trunk of a tree, we can readily recognize the small point in the centre which we call the pith or stele, the colored heart-wood, the sap-wood, and the bark. We will also note the great number of circles known as the *annual rings.* (Fig. 74.) In many trees, each ring represents one year's growth. We will also observe a large number of lines which radiate from the centre and are known as *medullary rays.* (Fig. 74.) In young stems these rays are composed of paren-

chyma cells and are a continuation of the pith cells; but in older stems they are frequently compressed into extremely thin, flat layers of cells separating the fibro-vascular bundles.

The bundles increase in number with the age of the plant. In young stems the bark is soft and greenish in color and can be readily separated from the underlying woody parts. In the older stems the outer bark is dead and frequently cracked and conceals the soft or true bark. In peeling the stem the separation sometimes occurs in the cambium. The increase in the number of cells in the dicotyledonous stems is confined almost entirely to the cambium layer of cells which produces new cells for both the xylem and the phloem. Therefore, it will be readily seen that the formation of the new layers of xylem cells results in increasing the diameter of the stem without increasing the inner diameter of the cylinder of bark. This increase of the size of the stem must necessarily exert a considerable strain on the bark covering, which results in the very slow splitting and peeling of the outer bark. This explains the roughness of the bark of most of our trees and the characteristic natural peeling of many others. As the old, outer bark is gradually shed, the newly formed inner bark becomes the outer and new layers are formed from below.

Cause of Annual Rings.—The formation of the cells of the xylem is not uniform throughout the season. In our northern climate, the cells formed in the first part of the growing season are larger and have thinner walls than those formed later. This difference causes the so-called annual rings.

Sap-Wood.—The light-colored sap-wood is composed of cells in which there is little or no growth, but which contain more or less protoplasm.

Heart-Wood.—The dark-colored heart-wood is composed of cells from which the protoplasm has disappeared. They are

dead cells but are sound and give support to the trees. Sometimes the heart-wood decays and the tree becomes hollow but continues to live and grow so long as the cambium is uninjured.

The root (Figs. 75 and 76) is composed of the same tissues as the stem, but they are arranged in an entirely different manner. In the centre is the *central cylinder* or *axis* made up of fibro-vascular bundles which are separated by thin layers of parenchyma. Immediately surrounding this *axis* is a comparatively thick zone of parenchyma cells known as the *cortex*. This

FIG. 75

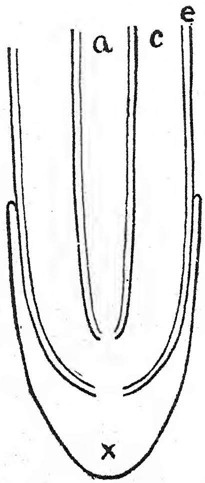


FIG. 76

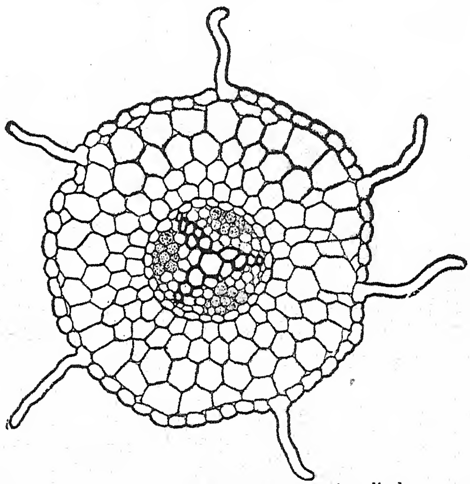


FIG. 75.—Diagrammatic longitudinal section of root tip showing: a, axis cylinder; c, cortex; e, epidermis; x, root cap.
FIG. 76.—Cross-section of root tip showing cellular structure and root-hairs.

is surrounded by a very thin layer of cells known as the *epidermis*. The epidermis of the very young roots gives rise to a great number of extremely delicate root hairs which penetrate the soil and take the water and necessary substances which may be in solution. (Page 26.)

The structure of the leaves varies somewhat in the different plants. Probably the most common form is that which we will describe. The typical leaf may be said to be composed of four layers of parenchyma cells supported by delicate frame work of fibro-vascular bundles. The upper layer of cells is the upper epidermis and consists of thick-walled, transparent cells; below this is the layer of *columnar* or *palisade cells* which are elon-

FIG. 77

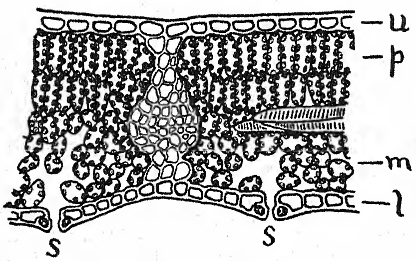


FIG. 78

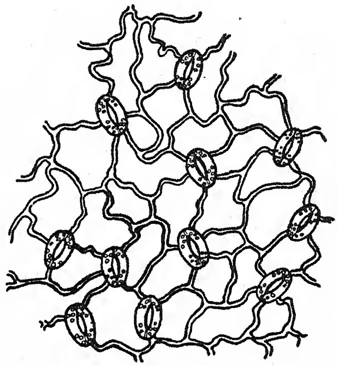


FIG. 77.—Cross-section of leaf showing: u, upper epidermis; p, palisade cells; m, mesophyll cells; l, lower epidermis; s, stomata.
FIG. 78.—Lower surface of leaf showing stomata.

gated, more or less cylindrical and placed at right angles to the epidermal layer; just below the palisade layer is a thick layer of loose, irregularly shaped parenchyma cells known as the *mesophyll;* just below the mesophyll is the last layer or *lower epidermis* which is very similar to the upper epidermis. The palisade cells are rich in protoplasm and in the green coloring matter which is known as the *chlorophyll.* The chlorophyll is usually confined to very definite small bodies known as *chloroplasts* and is essential for the photosynthesis work of the plant. (Page 115.)

In the lower epidermis will be found a considerable number of small openings or stomata (singular stoma) (Figs. 77 and 78), leading into the irregular tunnels or intercellular spaces found between the cells of the mesophyll. Each stoma or opening is between two crescent-shaped cells called *guard cells.* The function of these parts will be considered in Chapter X.

Hair-like Growth on Leaves.—The leaves of some plants are very smooth while others have more or less delicate hair-like growths known as trichomes. (Fig. 79.) (Chapter IV.) These trichomes are so numerous on the leaves of some plants as to give them the appearance of velvet. These structures are also found on the young stems of many plants. They are outgrowths of the epidermal cells and present numerous very interesting forms. Some of them are glandular in character, and cause the plant to feel sticky to the touch. They are, no doubt, protective in many ways.

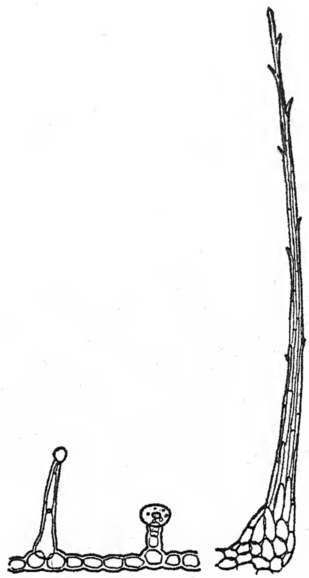


FIG. 79.—Trichomes or plant hair from leaf surface.

EXERCISES SHOWING MINUTE STRUCTURES

1. **Pith.**—Cut a very thin section of a pith, mount in a drop of alcohol and glycerine and examine under the microscope. Note the large, thin-walled parenchyma cells and the intercellular spaces between them. They resemble a large number of thin hollow balls thrown together and slightly pressed out of shape where they come in contact.

2. Examine a small piece of algæ (preferably Spirogyra) under the microscope. Note the size and form of the cells and the chromatophore.

3. Examine a small piece of algæ that has been kept in alcohol and stained with eosin. Note the protoplasm and nucleus.

4. Examine a very thin section of potato under the microscope and note the starch grains. Stain with dilute iodine and examine again.

5. Cut a very thin cross-section from the pith of corn stalk. Note the parenchyma cells and the fibro-vascular bundles. Study out the parts as indicated in the figures.

6. **Geranium Stem.**—Cut a very thin cross-section of the stem of a geranium. Note the parts as indicated in Figs. 67, 70.

7. **Woody Stem.**—Cut a very thin cross-section of a twig from a tree. Note the parts as indicated in Fig. 74.

8. **Many Forms of Cells.**—Make longitudinal sections of all of the above stems and find as many kinds of cells as possible.

9. **Leaf Structure.**—Hold a bit of a leaf between two pieces of pith and cut very thin cross-sections. Examine under the miscroscope and note the parts as indicated in Fig. 77.

10. Peel small fragments of epidermis from both lower and upper surfaces of a leaf and examine under the microscope.

11. **Root Structure.**—Hold a young root from corn or bean between two pieces of pith and cut very thin cross-sections. Examine under the microscope and note the parts as indicated in Figs. 75 and 76.

QUESTIONS

1. What do you understand by fibro-vascular bundles?
2. How are they arranged in the plant?
3. What do you understand by plant cell?
4. What are some of the different kinds of plant cells?
5. What do you understand by protoplasm?
6. What else do you find in plant cells?
7. What is the cambium? Where is it located?
8. Explain the difference between mono- and dicotyledonous stems.
9. What is meant by phloem and xylem? Where are they located?
10. What are the medullary rays?
11. What are annular rays?
12. What is meant by epidermis?
13. In what parts of the plant do you find chlorophyll?
14. What is meant by mesophyll?
15. What and where are the trichomes?

CHAPTER IX

CHEMICAL COMPOSITION OF THE PLANT

WE HAVE examined both young and mature plants and have studied the various organs of which they are composed. We have also learned something of the structure of these plant organs. Let us learn something of their chemical composition; something about the qualities that make them useful or unfit for food and other purposes. Of course, we have reason to believe that the different parts of the plant are unlike in chemical composition, for we know that they are different in structure and texture, and that we use them for radically different purposes.

Water, which is so essential for plant growth (Chapter I) is the most abundant and one of the most important compounds in the plant. We know that fruits and vegetables are juicy and we have seen the bleeding of trees when pruned too late in the season, and, therefore, it is not necessary to demonstrate that plants contain water. The quantity of water in the different parts of the plant varies from the very large amounts in juicy fruits to the very small amounts in dry grains. The following table shows some of the extremes:

Plant	*Percentage of water content by weight*
Cucumber (fruit)	96
Cabbage (leaves)	90
Beets, red (roots)	88.5
Apples (fruit)	83.2
Potato (Irish)	78.9
Potato (sweet)	71.1
Corn (green fodder)	79.8
Corn (dry grain)	10.9

We also know that plants contain carbon, for we have seen the charcoal which is formed as a result of burning a piece of

wood. But when the fragment of charcoal is burned we have a few ashes remaining. The chemist tells us that this ash contains small quantities of phosphorus, potassium, calcium, magnesium, sulphur, sodium, chlorine, manganese, aluminum, etc. The water, carbon and nitrogen which we know make up a considerable part of the plant have been carried off as vapor and gas during the process of burning.

The water is composed of two gaseous elements, hydrogen and oxygen. When wood burns or decays, the carbon (C) unites with the oxygen (O) of the air forming a gaseous compound known as carbon dioxide (CO_2), which is available for new plant growth. (Page 115.)

Starch.—We also know that plants contain *starch* which is composed of three elements, carbon, hydrogen and oxygen, combined as $C_6H_{10}O_5$. Starch is one of the most abundant plant substances and is one of the valuable plant products of commerce. It constitutes a considerable part of the dry substance of seeds, green fruits, fleshy roots, tubers, bulbs, fleshy leaves, etc., in which it can be readily detected by very simple experiments. Starch is one of the important food substances for both man and beast. Potatoes, sweet potatoes and other tubers and fleshy roots contain large quantities of starch. Grains, peas, beans and other seeds contain an abundance of starch. The starch not only makes these plants valuable for food but also for other purposes. Tapioca, some forms of paste and other articles of commerce are made from starch. The following table shows the relative amount of starch found in some common food plants, as estimated in percentage of dry weight.

Plant products	*Percentage of starch*
Seeds of navy beans	45
Seeds of peas	52
Seeds of corn	60
Seeds of wheat	68
Seeds of rice	68
Tubers of potatoes	80

The starch is found in definite bodies known as starch grains within the cells of the plant, and can be seen readily with the aid of the microscope. The size and form of the starch grains vary in different plants.

Sugar is another plant product very similar to starch, but it occurs in a much greater variety of forms. The most common type is the cane sugar ($C_6H_{12}O_6$) which is abundant in many plants and forms a valuable food product. It is found in the cell-sap and can be readily detected by simple experiments. It is especially abundant in sugar beets, sugar maple, sugar cane and ripened fruits. We all recognize the value of sugar for food and as an article of commerce. One of the great problems of the plant breeders is to increase the percentage of sugar in the sugar-producing plants. (Chapter XV.) The amount of sugar in the sugar beet has been increased from 7 to 15 per cent by scientific methods of plant breeding.

Carbohydrates.—The cell-walls are composed of cellulose which is made up of the same elements as starch and sugar, but they are also infiltrated with various other substances. Cellulose is the most important plant compound in the manufacture of paper. Cellulose is also used extensively in the manufacture of the many celluloid articles on the market, and it is also used in the making of gun cotton and other high explosives. Many plants also produce gums which are composed of these same elements and some of which are important articles of commerce. The starch, sugar, gums, and cellulose are known as carbohydrates; that is, their hydrogen and oxygen is always in the ratio of two to one.

Fats.—Many plants also contain *fats* and *oils* which are composed of the same elements as the carbohydrates (*i.e.*, hydrogen and oxygen), but the hydrogen and oxygen ratio is never two to one. The fats and oils are known as *hydrocarbons* and are usually most abundant in the seeds, especially nuts. They

are used for food, medicine, soap making and many other purposes and are among the most important articles of commerce.

Proteins.—Plants also contain a third group of foods, known as proteins or proteid foods which are composed of carbon, hydrogen, oxygen and nitrogen, and are among our most important food substances. They are especially abundant in seeds and the food value of many plants over others depends almost entirely on their percentage of protein. They may be associated with the carbohydrates, but in some cases are borne in separate cells. The great value of clover, cowpeas, soybeans and related plants for stock feed, and of beans and peas as food for man depends primarily on their protein content.

Plants contain many other compounds, some of which are referred to as waste products. Among the most important of these compounds are the following:

(a) **The essential (or volatile) oils,** which are entirely different from the true oils previously referred to. They may occur in any part of the plant, but are especially abundant in the foliage and flowers. Most of the odors of plants are due to these *essential oils,* many of which are extracted and used in the manufacture of medicines, perfumes, soap and other articles of commerce.

(b) **Gums and resins** of various kinds are familiar articles of commerce. Among the most important are turpentine, resin, balsams, gum-camphor, gum-arabic and gum-tragacanth.

(c) **Organic acids** are very numerous and are especially abundant in certain fruits. Among the most common organic acids of commerce are oxalic, malic, tartaric and citric acids.

(d) **Tannins** are abundant and are found in the great majority of the higher plants. They are used for the making of hides into leather, in medicines and for other purposes.

(e) **Alkaloids** are abundant plant products from which we obtain many valuable medicines and some of our most danger-

ous poisons. Among the most familiar are quinine, strychnine, cocaine and morphine. In this connection, it is well to remember that about 90 per cent of our medicines are of plant origin and that much of the early work in botany was for the discovery of new drug plants with which to relieve the sufferings of mankind.

EXERCISES SHOWING THE COMPOSITION OF PLANT TISSUES

1. **Ash in Leaves.**—Weigh a bunch of green cabbage or lettuce leaves. Dry them in an oven. Weigh again and compute percentage of water. Burn the leaves, weigh and compute the percentage of ash.

2. **Water in Seeds.**—Put a few seeds in a test tube, plug with cotton and heat gently so as not to scorch the seeds. Hold the tube as nearly horizontal as possible while heating. Do you see signs of water on the glass?

3. **Ash in Wood.**—Put a piece of wood in a test tube and heat until a piece of charcoal (carbon) is formed. Burn the charcoal to ashes. Shake the ashes in water. Do they dissolve?

4. **Tests for Starch and Sugar.**—Put a little commercial starch and a little sugar in separate test tubes of water, and shake. Do they both dissolve? Add a few drops of iodine to the starch and note the change in color. This is the test for starch. Add a small amount of Fehling's fluid, a few drops at a time; a brick red color indicates the presence of sugar. This test will not work with cane sugar unless the solution has been boiled with dilute acid before adding the Fehling's fluid.

Fehling's solution can be made in the laboratory. It consists of two solutions: (*A*) 36.64 grams of pure powdered copper sulphate in 200 c.c. of water. (*B*) 150 grams of Rochelle salt and 50 grams caustic soda in 500 c.c. of water.

Keep the two solutions separate and mix before using as follows:

2 parts of solution *A*.
5 parts of solution *B*.
10 parts of water.

5. **Carbon in Sugar.**—Put a little sugar in a test tube and heat slowly until you have a black mass of carbon. Note what occurs during the process and explain.

6. **Testing Seeds and Fruits.**—Test fruits, tubers, fleshy roots and various other parts of plants by applying the starch and sugar tests to freshly cut surfaces.

7. **Examining Potatoes and Apples.**—Cut very small, thin slices of

potato and apple, mount in water and examine under the microscope. Add a drop of iodine and note the effect.

8. **Starch and Sugar after Germination.**—Crush a few well germinated seeds and put in two test tubes, fill about one-third full of water and shake thoroughly. Boil and test for starch and sugar.

9. **Changing Starch to Sugar.**—Make a thin paste by boiling starch in two test tubes of water. Allow to cool and add a small amount of diastase or saliva to one. Keep in a warm place for 24 hours and test both for sugar.

10. **Oil in Seeds.**—Crush a seed of castor bean or the kernel of some nut between the fingers and thumb and note the oily character. Rub the seed or nut on a piece of paper for the same purpose. Tie a small amount of crushed seeds or other plant material in a bit of cheese-cloth and soak in a small dish of benzine; squeeze and remove and allow the benzine to evaporate. Any oil that may be present will be found in the dish. Make a list of vegetable oils of commercial importance and give their sources.

11. **Protein in Flour.**—Tie a small quantity of wheat flour in a bag and knead under a stream of water. The sticky dough that remains is largely protein. The starch was mostly washed out by the stream of water.

12. **Starch and Protein in Wheat.**—Cut very thin slices of wheat grain and examine under the microscope. Test for starch. Note that the starch is in the center and in very thin-walled cells. Also note that the proteid (aleurone) is in cells surrounding the starch. Also note the hull is made up of the union of seed and ovary coats.

QUESTIONS

1. What compound is found in greatest amount in the plant? How does it get into the plant? Is the total amount entering the plant retained? If not, how does it pass out?
2. Explain the results obtained in the drying and burning of a piece of wood. How do these elements and compounds become a part of the wood?
3. What substances found in plants are useful as foods for animals? In what parts of the plant are they found?
4. Give a list of commercial products of plants. Tell where found and their uses.
5. Mention several plants or products rich in sugar.
6. From what plants is starch obtained commercially?
7. What plants yield oil for commerce?
8. Mention several stock feeds rich in protein.

CHAPTER X

PLANT FOODS AND PLANT GROWTH

We have learned something about the important substances found in plants, the starches, sugar, oils and proteids which make them valuable for food. We have also learned that they contain many other substances of more or less value in commerce. We also know that many plants are grown for their fibre which is used in many manufacturing industries, and we also use the wood of many of the larger plants for many purposes. Therefore, it is very evident that the plant kingdom produces a very large number of useful plants. Let us now study the source of these products and the processes by which they are formed.

Plants are unlike animals in that they use comparatively simple compounds which are obtained from the soil and air and transformed into true food materials for their own growth; animals cannot use such simple compounds, but are compelled to feed upon plants from which they secure already manufactured or true foods, carbohydrates and proteids. Therefore, all animal life is dependent either directly or indirectly on plant life for its existence. The most important raw foods or compounds that the plant gets from the earth are water (H_2O), ammonia compounds (NH_3), sulphur, potassium and phosphorus, and various salts. The most important raw foods from the air are carbonic acid gas or carbon dioxide (CO_2) and very small amounts of oxygen (O).

The energy with which these raw materials are transformed into true foods comes from the sun in the form of heat and light. Therefore, all life (both plant and animal) upon the earth is dependent upon the sun for its existence. These raw foods are transformed into true foods in the plant before they can be

used even for its own growth. However, the process by which these simple compounds are transformed into true food materials is imperfectly understood.

The amount of water in the soil varies with the amount of rainfall and the texture of the soil. Coarse, sandy soils are poor retainers of water as compared with the very fine clay soils. Humus soils are excellent retainers of water, and this fact, together with their richness in organic matter, makes them especially good for agricultural purposes. It is very evident that water acts as a solvent for the available soil substances and salts, and is then taken up by the root-hairs. We have already studied the root-hairs, and know that they are long, delicate cells containing very active living protoplasm and a watery substance called *cell-sap*. This cell-sap is water containing salts, acids and sugars. The root-hairs are evidently well filled and somewhat distended. When cells are distended in this manner they are said to be turgescent, or in a state of turgor. All the active cells of a normal, growing plant are turgid and it is this condition which enables the soft parts of a plant to maintain their form and position. When cells lose their turgidity the plants wilt.

Osmosis.—It is well known that when a substance dissolves in a liquid it gradually diffuses until equally distributed. If two solutions of equal density are separated by a plant or animal membrane, the substances in solution will gradually diffuse through the membrane until the two solutions are uniform throughout. This is known as *osmosis*. (Fig. 80.) If two solutions of unequal density are used there will be a flow from the less dense to that of the greater density. When a plant is growing under suitable conditions, the solution of greater density is within the cells, especially the root-hairs; and the solution of lesser density surrounding them. The delicate root-hairs ramify among the extremely fine particles of soil. The soil,

water and the salts in solution pass into the cells of the root-hairs and thence into the fibrous and trachearv tissues of the root and thence through the same and probably other tissue of the sap wood of the stem into the leaves where a considerable part of it is given off by *transpiration.* (Chapter VIII.) The exact process by which water passes through a growing plant is

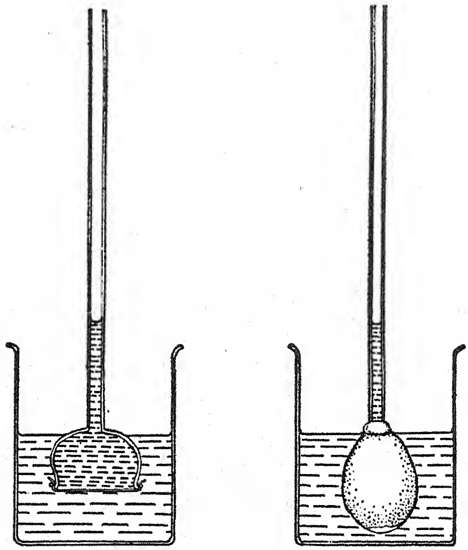


FIG. 80.—Apparatus for demonstrating osmosis; thistle tube on left and egg on right.

not understood. Some of the acid within the root-hairs passes out (*exosmosis*) and helps to dissolve the raw food compounds in the soil, thus making them more available. If the character of the soil is such that the water solution is of greater density than the contents of the plant cells, the plant cannot live in it, and if a plant should be set in such soil it would wilt very quickly because of the loss of water which would pass out to the soil.

Transfer of Water.—The process by which water is transferred from one part of the plant to another part is very imperfectly understood, but we do know that it is transferred from place to place and that it is carried upward in great quantities against the tremendous force of gravity. We know that the force necessary to lift this column of water to the top of very tall trees must be enormous. We know also that this activity is much greater at certain seasons of the year than at others. We have all observed the bleeding of trees and vines when pruned too late in the spring, and know that considerable injury may result from this practice.

Transpiration.—We have said that a considerable amount of water is given off through the leaves by *transpiration.* This is also true of the new shoots and such other green parts as the plant may possess. The transpiration of water should not be confused with evaporation. The latter process takes place from the free surface of a body of water and is controlled by the physical conditions of the air, but the former is controlled by the structural character of the plant and the living protoplasm of the plant cells. The water in the plant must pass through the cell-walls into the intercellular spaces of the mesophyll to which we have previously referred (Chapter IV), and then passes out through the stomata by a process of diffusion.

Of course, when the air is dry the transpiration of water will be much greater than when moist. The number of stomata varies greatly in different species of plants, those growing in dry places usually having fewer than those growing in wet places. The amount of water which plants take from the soil and give out through the leaves during a growing season is enormous, but extremely variable when we compare plants living under different conditions. It is estimated that some of our common farm crops take up and give off an average of 300 pounds of water in the production of one pound of dry material, although in some plants it is three times this amount.

A Change of Gases.—The giving off of water through the stomata is associated with a change of gas by transfusion between the air within the intercellular spaces of the leaf and the air on the outside. Therefore, as the water passes outward through the stomata, the carbon dioxide (CO_2) of the air passes into the intercellular spaces, is absorbed by the protoplasm of the mesophyll cells and immediately dissolved in the cell sap, thus forming carbonic acid ($CO_2 + H_2O = CH_2O_3$). The action of the sunlight on the chlorophyll results in the breaking up of this carbonic acid and the recombination of the elements with the elements of water into other compounds. This delicate and complicated process is very imperfectly understood, and the first result that we can recognize with any degree of certainty is glucose or grape sugar ($C_6H_{12}O_6$).

Plants and Animals Help Each Other.—We know that the process results in the liberation of free oxygen ($6CO_2 + 6H_2O = C_6H_{12}O_6 + 12O$) which is given out through the stomata and is essential for the life of animals. Therefore, we see that animal and plant life are more or less inter-dependent, but it is very evident that animals are more dependent upon plants than plants are upon animals. Plants utilize the carbon dioxide which is exhaled by the animals, but they could readily obtain this supply from other sources. Animals utilize the oxygen given off by plants, and are absolutely dependent upon plants for their food supply.

The formation of carbohydrates, that is, starches and sugars, from these crude materials (water and carbon dioxide) by the action of sunlight on the chlorophyll is known as *photosynthesis* and is the most wonderful and most mysterious process in all nature. With this as a beginning, we have the basis for the formation of innumerable other plant and animal products. A small part of this organized food is used immediately for cell formation and growth, but the greater part is stored for future use.

Grape sugar which is formed in the green parts of plants can be readily transformed into starch by the loss of one molecule of water ($C_6H_{12}O_6 - H_2O = C_6H_{10}O_5$). In some plants, such as the sugar beet and sugar corn, the sugar is transferred directly and stored as such without change. But in most plants it is very quickly transformed into starch, which is reconverted into sugar during the night and transferred to other parts. Therefore, if the leaves are examined early in the afternoon they will be found to be very rich in starch as compared with their condition before sunrise.

Other Organic Compounds Formed.—We know that starch and sugars are the most abundant food products of the plant; that they are especially abundant in vegetables, fruits and seeds. But we also know that there are other substances, such as hydrocarbons (fats and oils); and the proteins, which contain nitrogen (and some sulphur and phosphorus). These are among the most important food products, but we know very little about their formation.

Mineral Substances.—Plants take a great many minerals from the soil. The most important are phosphorus, potassium, calcium, magnesium, sulphur, iron, sodium, chlorine, silicon, manganese and aluminum. These elements go into solution in the water of the soil and then pass into the root-hairs in the manner already described. They may be found by making a chemical analysis of the ash of the plant. They vary in proportion in different species of plants, in plants at different ages and in different parts of the same plant.

These minerals exist in varying quantities in the soil, but their proportions may not be such as are needed by the crop, or they may not be in such form as to be available as plant food. Therefore, the progressive farmer, who is familiar with his soil and with the needs of his crop, makes use of manures and commercial fertilizers to overcome these deficiencies.

Nitrogen and Protein.—One other most important element

of plant food which we have not taken into consideration is *nitrogen,* an element which is essential in the formation of protoplasm and protein. The food value of many plants depends upon their protein content. Nitrogen constitutes 78 per cent of the atmosphere, and one might readily suppose that the plant could secure its supply from that source. But such is not the case. The free nitrogen of the air is not available for plant food. It must be united with hydrogen to form a nitrate before it can be utilized by the growing plant. There are several sources of nitrogen for plant food.

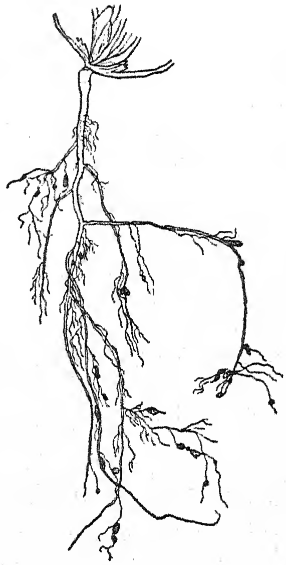


FIG. 81.—Root of legume showing tubercles.

(*a*) By the decay or disintegration of organic matter; *i.e.,* dead plants and animals and their waste products. This is brought about by millions of minute organisms of decay known as *bacteria.*

(*b*) By certain soil bacteria which live in the tubercles or nodules (Fig. 81) on the roots of leguminous plants and which enable the plant to take the nitrogen from the air, and combine it with hydrogen, thus forming ammonia compounds.

(*c*) By rainfall, which carries the nitrogen of the air to the soil where it becomes available for these bacteria.

(*d*) By electrical discharges (lightning) producing nitrous and nitric acids which are carried to the earth by the rainfall. The first and second of these are the most important.

Importance of Humus.—The first of these sources shows the importance of utilizing animal manures and decaying plant materials as fertilizers. These decayed animal and plant prod-

ucts are called *humus*, and we have long recognized that humus is essential for plant growth. The second shows the importance of the use of leguminous plants to increase the nitrogen content of the soil and explains why clovers, alfalfa, cowpeas, soybeans, vetch and similar plants are of such great importance as soil improvers.

Circulation.—Knowing that plants take in water from the soil, that it rises through the plants and is given off through the foliage, naturally indicates that the plant possesses a circulatory system similar to that of animals. Although the circulation is through definite parts of the plant tissues, it is not through a definite set of tubes and does not have a propelling organ or pump such as the heart of the animal. The water rises in the wood (or xylem) part of the stem and carries the mineral substances of the soil in solution. But this does not complete the problem of circulation. Very little of the manufactured plant food is stored in the parts in which it is formed but is transferred to fruits, seeds, tubers, bulbs, roots and other parts for storage. This transfer is primarily through the outer (or phloem) part of the stem. We do not understand just how this transfer is accomplished, but much of the food must undergo modifications, must become soluble, before it can be moved. The carbohydrate is probably moved while in the form of sugar (glucose), and the fats and true soils as glycerine and fatty acids, and the proteids in a form known as amides.

EXERCISES SHOWING PROCESSES IN PLANT GROWTH

1. **Osmosis Through a Bladder.**—Tie a bit of bladder or sausage casing or parchment over the large end of a thistle tube; partly fill the tube with molasses and immerse the large end in water until the two liquids are on a level. Make observations at intervals of one hour and explain the phenomena.

2. **Exosmosis and Endosmosis.**—Peel some fleshy root such as carrot, turnip or beet and cut in slices about ¾ x 1½ inches and about ⅛ inch in thickness. Put a few of them in distilled water and a few in a salt or sugar solution. Examine after a few hours and explain. Now

transfer them, putting those that were in the solution in the distilled water, and those that were in the water in the solution. Examine after a few hours and explain.

3. **Movement of Plant Fluids.**—Cut * a stem of a Begonia two or three inches from the surface of the soil, and place the severed part in a glass of water that has been colored with some analine dye or red ink. After twenty-four hours, remove and cut the stem at various points and examine. Fasten a small glass tube on the stump by means of adhesive tape, and keep the roots well watered. Note the rise of water in the tube. Explain.

4. **Transpiration.**—Take a small actively growing plant and tie a piece of sheet rubber over the pot allowing the plant to project through a small opening; invert a glass over the plant and note the moisture which collects within the next few hours. Where did it come from? Cut a bunch of fresh growing plants or a cabbage and weigh. Allow to wilt and dry and then weigh again. Dry in an oven, but do not char, and weigh again. Explain.

5. **Plant Food.**—Secure a quantity of coarse, clean sand, and fill two flower pots or cans of equal size with equal quantities. Plant several grains of corn of approximately the same size and character in each. Water one from time to time with rain water or distilled water and the other with soil solution. Soil solutions may be prepared by filling a large pail two-thirds full of rich soil or well rotted manure and then adding enough water to make a thin slop. Stir, allow to settle and draw off the water. Refill with water and allow to stand until needed again. In which pot do the plants grow best? Why?

6. **Moisture in Wood.**—Weigh a piece of green wood. Heat until thoroughly dry. Weigh again. What has it lost and how much?

7. **Carbon in Wood.**—Burn the wood until charcoal is formed. This is almost pure carbon. Weigh again. What has been lost and how much?

8. **Ash in Wood.**—Burn the charcoal. What have you remaining and how much?

9. **Carbon in Sugar.**—Put a little white sugar in a test tube and heat. What happens? Explain.

10. **Study of Oxygen.**—Mix a teaspoonful of potassium chlorate with about one-fourth the amount of finely powdered manganese dioxide. Put the mixture in a large test tube or small flask. Close the container with a stopper through which a small delivery tube passes. Fix the container in a slanting position on an iron stand, and run the free end of the delivery tube into a tray of water. Heat the mixture gently with gas or alcohol flame. Fill several bottles with water; invert one over the mouth of the delivery tube in such a manner that the water will be

---

* The stem should be held in the liquid during the cutting so that the cut surface is not exposed to the air.

forced out by the gas. When all the water has been forced out, cover the mouth of the bottle with a card and invert. Repeat until three or four bottles are filled.

This gas is oxygen. Note its color. Thrust glowing pieces of charcoal into the bottles and note the result. Explain.

11. **Study of Carbon Dioxide.**—Put some small fragments of marble into a flask thoroughly closed with a cork through which has been passed a delivery tube as in Exercise 10, and a small funnel or thistle tube. Pour dilute hydrochloric acid into the funnel until the lower end is covered. Collect the resulting gas (carbon dioxide) as in Exercise 10. Run a little of the gas into lime water and note the result. Take a little fresh lime water and blow into it through a straw or tube. Note the result. Explain.

12. **Burn a piece of charcoal** in a bottle of pure oxygen. Remove quickly, pour in lime water and shake. Note the result. Explain.

13. **Study of Hydrogen.**—Put a few fragments of zinc into the same or a similar apparatus as used in Exercise 10. Add the dilute hydrochloric acid but allow the gas to be given off for some minutes. Then collect a bottle of the gas (hydrogen) and place upside down on a table. Darken the room and thrust a burning match into the inverted bottle. Note the result.

14. **Study of Nitrogen.**—Fasten a bit of candle to a cork and float in a vessel of lime water. Light the candle and cover with a wide bottle so placed that the edges are under water. When the candle goes out, cover the mouth of the bottle with card-board or cork and reverse so as to retain all the water that has risen in the bottle. Shake thoroughly, and allow to stand until the upper part is clear. What has been used by the burning candle? What gas has been formed as indicated by the lime water in the bottle? The gas remaining in the bottle is nitrogen.

QUESTIONS

1. What are the three great groups of substances found in plants?
2. Of what elements are each of these food substances composed?
3. What are the sources of these elements?
4. What other elements are found in plants?
5. What relation does the texture of the soil bear to the water content?
6. What do you understand by humus?
7. What do you understand by turgor?
8. What do you understand by osmosis?
9. Why do plants wilt?
10. What do you understand by transpiration?
11. What do you understand by photosynthesis?

CHAPTER XI

THE GYMNOSPERMS

THUS far we have devoted our time to the study of the higher plants, that is to the plants which produce flowers and seeds. This great group of trees, shrubs and herbs presents by far the most conspicuous types of vegetation and includes our most important agricultural crops. But we must now consider the *gymnosperms* (for classification, see Chapter V), that great group of seed-bearing plants which do not produce true flowers. They are also called coniferous or cone-bearing plants because of the cones which contain the seeds. The largest, most important and best-known group is the order *Pinaceæ* which are widely distributed throughout the world especially in the northern hemisphere. They are the pines, spruces, firs, balsams, larches, cypresses, cedars, hemlocks, arbor vitæ and the giant red oaks of our Pacific coast.

Structure of Stems.—The general character and gross structure of the stems and roots is somewhat similar to the *angiosperms,* but the leaves are modified until in most cases they are described as needles. These needles may be compared to the midrib of an ordinary leaf, but when cut in cross-section and examined under the microscope they show a thick cuticle and epidermis covering a few layers of sclerenchyma cells (Chapter VIII), which in turn cover the chlorophyll bearing parenchyma (Chapter VIII). The small size and peculiar structure of the leaves make them especially well suited for withstanding either dry or cold climates. Most coniferous trees shed their needles gradually and, therefore, are in foliage the entire year. For this reason they are known as *evergreens* and are especially suitable for ornamental plantings. Some few conifers such as the

bald cypress and larch are *deciduous, i.e.,* shed their entire foliage each year and are bare during the winter season.

A cross-section of the stem will show the annular rings and medullary rays the same as in dicotyledonous plants. Very thin sections should be made and mounted in water for study under the microscope. Each section is cut at right angles to the other two as follows:

(*a*) The cross-section which will show the varying thicknesses of the cell-walls by which the annular rings are produced, the large thin-walled cells of the late summer growth. It will also show the medullary rays and large resin ducts. (*b*) The radial section which is cut longitudinally and on a plane passing through the axis of the tree (*i.e.,* quarter sawed) will show the peculiar markings of the cells (*tracheids*). By studying carefully made tangential sections which are also longitudinal but at right angles to the radial section we can get some idea of these peculiar markings.

The cones are of two kinds, *staminate* and *pistillate.* They correspond to bunches of staminate and pistillate flowers. We are most familiar with the *pistillate* (or carpellate) (Fig. 82, *c*) cones and will give them first consideration. They become the mature cones which we find hanging on the trees. These cones are made up of scales, corresponding to needles or leaves, but instead of being arranged in circles as in the case of a true flower, they are arranged in spirals. You will also note that when they spread apart they each bear two winged seeds.

But let us examine an immature cone such as we will find early in the spring. (Fig. 82, *c.*) Each cone is small and the scales naturally spread so as to expose two *ovules* (*macrosporangia*). (Fig. 82, *d.*) This is quite different from the true flowering plants in which the ovules are always enclosed in an ovary.

Pollination.—In the spring we will also find clusters of very small staminate cones. (Fig. 82, *a.*) Each scale of these

small cones is a *stamen* (*sporophyll*) bearing *sacs* (*microsporangia*) filled with great quantities of yellow *pollen grains* (*microspores*) which fall in showers and are scattered by the wind. These pollen grains are provided with flattened extensions of the cell-wall, forming wings for their ready support in the air.

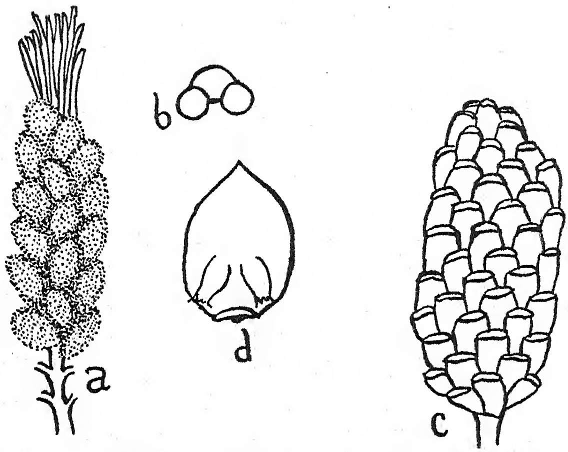


FIG. 82.—a, cluster of staminate cones; b, pollen grain; c, pistillate cone; d, scale from pistillate cone showing two ovules.

Some of the pollen is caught in the pistillate cones and falls upon the exposed ovules. The scales close and the pollen grain produces a delicate tube which penetrates the ovule, reaches the egg and results in *fertilization* similar to that described for the angiosperm. (Chapter VI.) This process cannot be followed except by the study of carefully prepared slides with the aid of the microscope. However, the interval of time between pollination and the maturity of the seed is much greater than in most angiosperms. The seed cone enlarges rapidly, but the seeds are not mature until late in the summer of the following year.

Cycadales.—Another very interesting group of the *gymnosperms* is the order *Cycadales* which is mostly tropical in habit. In this order we find the *Cycas revoluta* which is frequently grown in greenhouses. Its chief point of interest botanically is in the fact that it possesses many characters in common with the ferns and forms a sort of connecting link between the *Gymnosperms* and the *Pteridophytes* or ferns.

We all readily recognize the great value of the *Gymnosperms.* Many of them are among our most important forest trees from which we derive enormous amounts of lumber for building purposes and cabinet making. They also furnish our commercial supply of turpentine, resin and balsams. The cypress is used extensively for telegraph and telephone poles. The use of evergreens for ornamental plants is directly connected with the nursery business and landscape gardening and involves very large expenditures of money.

EXERCISES WITH GYMNOSPERMS

1. **Examine a number of evergreen** trees and note their straight shaft, mode of branching and general form.

2. **Growth and Leaves of Pines.**—Examine a pine tree and note the long shoots that are produced each year. Also note the short shoots composed of clusters of needles. Count the needles in the clusters in the different kinds of pines that may be available. Is the number constant for each species?

3. **Examine a needle carefully;** make cross-sections by cutting the needle in a bit of pith and examine under the microscope. Note the thick cuticle, the thick epidermis, the sclerenchyma and the chlorophyll-bearing parenchyma.

4. **Twigs of Cone-bearing Trees.**—Cut across radial and tangential sections of a branch from a cone-bearing tree and examine under the compound microscope and note the points referred to in the text.

5. **Cone Flowers.**—Examine young staminate and pistillate cones and note the points referred to in the text. (This material can be collected in the spring and preserved in alcohol or formalin.)

6. **Pollen Grains.**—Examine some of the pollen grains under the compound microscope.

7. **Seeds and Cone.**—Examine a mature cone. Remove some of the seeds and examine.

8. **Study Seedlings.**—Plant some of the seeds and note characters of the seedlings.

9. **Greenhouse Gymnosperms.**—Visit the greenhouse and ask to see a *Cycas revoluta.*

QUESTIONS

1. What do you understand by *Gymnosperms?*
2. Compare the leaf of a Gymnosperm with that of an Angiosperm.
3. What do you understand by deciduous?
4. Are any of the Gymnosperms deciduous?
5. Have you seen any of these in the winter condition?
6. Name the parts of the staminate and pistillate cones of a coniferous tree.
7. Compare these parts with the corresponding parts of a true flowering plant.

CHAPTER XII

ECOLOGICAL RELATIONS

The growth of the plant is influenced by many factors, among the most important of which are water, soil, temperature and light. The combination of these four factors may not be such as to give the maximum in growth and productiveness; for while one or two of these factors may be in the correct proportion for the best growth of the plant, the other two may be in proportion unsuited for the greatest possible development. The plant is also influenced by animals, wind currents, and many other factors too numerous for discussion at this time. When a factor is such as to kill or prevent the growth of the plants of any particular species, it becomes a limiting factor in the spread of the species regardless of the character of the other factors. Lack of water may prevent the spread of a species into a territory when all other factors may be satisfactory. This is well illustrated by the great desert regions of the world which produce abundant vegetation when subjected to irrigation. Any species of plants will extend its range as fast as the controlling factors will permit, and will reach its maximum development where the combination of the factors is best suited to its existence and its minimum where it is most unsuitable.

Water.—We have already learned that plants cannot live without water and that it is the most abundant compound in most plants and also one of the most important. It passes into the plant by means of the root-hairs and passes out of the plant by transpiration, mostly through the leaves. We have also learned that many plants are composed almost entirely of water. However, plants differ in the amount of water required for their

existence. Some plants float in the water and have no direct connection with the soil; others are rooted to the soil but float in the water (water lilies). Some are rooted in the mud but extend far above the water (cat-tails); some grow in wet soil; still others grow in dry soil and are easily killed by too much

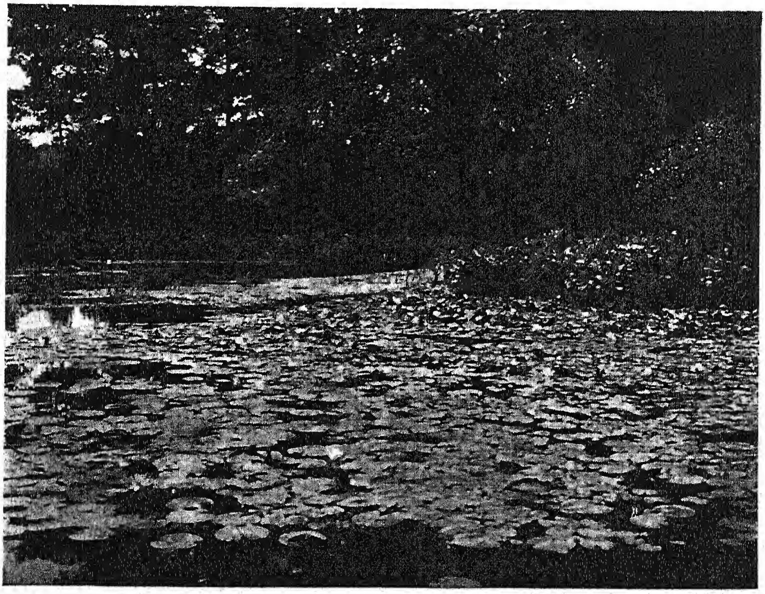


Fig. 83.—Zone formation of vegetation dependent upon depth of water.

water. These facts enable us to group plants into *societies* dependent upon their water requirements. (Figs. 83 and 84.)

The Hydrophyte societies are made up of those plants which live in the water or in very wet swampy soils. Ponds and lakes in which the water varies in depth frequently show many of these societies to an advantage; the floating plants in the moderately deep water, the cat-tails near the margin and the willows on the margin. Rice is one of the few hydrophytes which is of great agricultural importance.

The Mesophyte societies are those made up of plants which require a fair amount of rainfall. The forest and prairie plants and most of our agricultural plants are mesophytes.

The Xerophyte societies require very little water and include the desert plants.

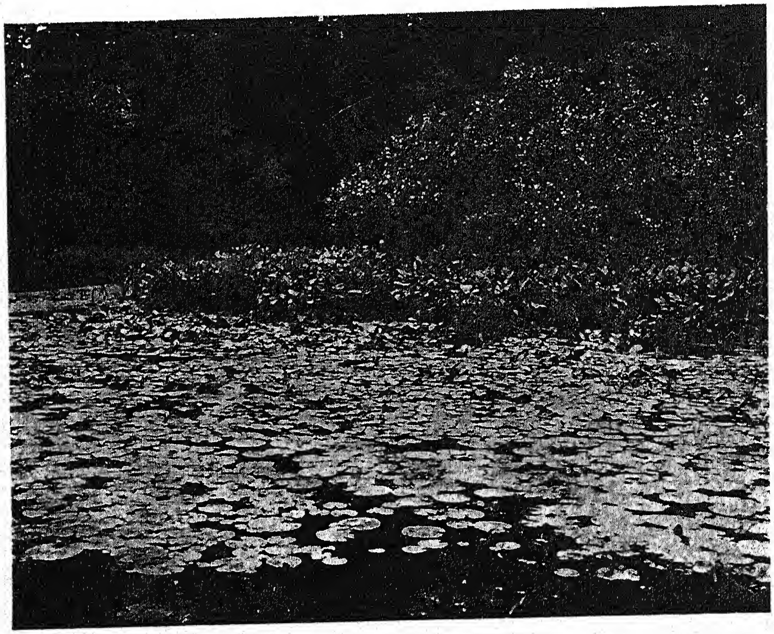


FIG. 84.—Zone formation of vegetation dependent upon depth of water.

In addition to these societies we have also

The Halophytes or those plants which grow in salt water and salt marshes, and

The Tropophytes which are mesophytic in habit for a part of the year and xerophytic in habit for the remainder.

Soil.—The majority of plants with which we are familiar grow in the soil, but we must not forget that a great number of

species of plants live in the water, while others live either parasitically or saprophytically on plants and animals. The soil in which plants live must have a suitable texture and must furnish certain elements which constitute most of the crude food materials of the plants. Since our agricultural crop plants are dependent upon the soil and since the animals are dependent upon the plants, it is evident that all animal life is dependent upon the soil. If we are to understand plant growth we must know something about the soil in which the plants grow.

The various soils are made up of numerous small particles of disintegrated rocks of various kinds, in which is usually mixed more or less decaying or decayed organic materials. The disintegration of the rocks is due to the freezing of the water which penetrates the minute crevices, to the grinding action of moving masses of ice, to the mechanical and solvent action of water and to many other minor influences. Soils are designated as gravel, sand, sandy loam, loam, clay, etc., dependent upon the coarseness or the fineness of the particles of which they are composed. The variation in the texture of the soil results in variation in its power to retain water.

The most important elements in the soil which either serve as food or influence the growth of plants are phosphorus, potassium, calcium, magnesium, sulfur, iron, sodium, chlorine, silicon, manganese, aluminum and nitrogen. All of these except the last can be found in the ash of the plant and of course must have been taken from the soil by the plant. These elements may be in the soil in proportions too great or too small for the needs of certain plants and satisfactory for others, or may be present, but in such a form as to be unavailable for the plant. Since the different species of plants are unlike in their requirements we find them more or less in groups dependent to some extent upon the character of the soil in which they grow.

Nitrogen Obtained from the Air.—Probably the most im-

portant of all the elements is the nitrogen which is essential for all plants and animals. Nitrogen is very abundant in the air, but the plants cannot make use of it in this free form. However, the air penetrates the soil and its nitrogen is seized upon by certain bacteria and fungi and fixed in the form of nitrates which can be used by the plants. (Chapter X.) This gives us one good reason for keeping the soil in which we are growing plants in loose condition. Nitrogen is also carried down and into the soil by rainfall. The bacteria found in the tubercles of the leguminous plants are the most important organisms in this work. Nitrogen is also obtained from decaying organic materials and this is one reason that humus is so important in agricultural lands.

Use of Fertilizers.—If the soil does not contain these food elements in the proper proportions or if any of them are unavailable, the farmer endeavors to overcome its deficiencies by the application of fertilizers, such as stable manure, bone meal, nitrate of soda, rock phosphate, potash, lime, etc., or by the growing of the leguminous plants or by both. In order to do this to the best advantage it is important that he understand the crop plants to be grown and their food requirements. The elements most likely to be lacking in farm soils are nitrogen (N), phosphorus (P), potash (K), and sometimes calcium (Ca).

Temperature.—This is another factor of plant growth which we very readily recognize and we know that certain fruits such as oranges and bananas grow only in tropical and subtropical countries, and that many other plants are limited in their range by the temperature. In traveling across the country we easily see that forest and prairie sections can be readily divided into smaller areas, such as the pine forest, oak forest, beech forest, etc. We also recognize great belts or areas of agricultural crops, such as the corn belt, cotton belt, wheat belt, peach belt, etc. On the boundaries of these belts we frequently find these

crops grown with considerable difficulty owing to droughts, frosts and other factors.

Light.—This is also an important factor which is very generally recognized. Our attention has been called to the fact that plants turn to the light and that their foliage is adjusted to receive the light to the best advantage. (Chapter IV.) But a little careful observation will show us that while some plants thrive best in the direct rays of the sun others are always found growing in the shady places. It is now well known that some of our agricultural crops thrive much better in the shade than in the open. Coffee is very generally grown in the shade of larger trees and many plants are grown in an artificial shade produced by slat coverings or by large cheesecloth tents.

These and many other factors of nature which influence the spread of plants have given rise to that phase of botany known as *Plant Geography.*

PLANT GEOGRAPHY

Plant geography is so closely associated with Ecology that it is practically impossible to separate the two subjects by well-defined boundaries. In our early study of geography we learned that the earth was divided into five zones: Arctic, North Temperate, Torrid, South Temperate and Antarctic, and we soon learned to associate these zones with cold, temperate and hot climates. But a little later we learned that countries in the same parallels of latitudes did not necessarily have the same temperature; mountainous regions in the torrid zone might be cold as Iceland; the Gulf current makes England much warmer than points on our Atlantic coast which are much farther south. It is very evident that elevations, mountains and water barriers and the ocean currents exert very pronounced influences on the temperature of a country and its plant growth.

A little later we learned that rainfall was fully as important as a climatic factor as temperature and that it had fully as much influence on the character of the vegetation. Probably the greatest rainfall in the United States is over a small area of Gulf coast extending from western Florida to a short distance west of New Orleans, a section of the country well adapted to growing rice and sugar cane. The rainfall of most of the southern states is somewhat higher than for the states north of the Ohio River, but cotton has reached its northern boundary far south of the river. The rainfall of the Rocky Mountain Plateau is lower than for any other part of the United States, giving us a great area of country frequently referred to as the American desert.

EXERCISES ON PLANT RELATIONS TO SURROUNDINGS

1. **Moisture and Germination.**—Fill two small flower pots with soil of the same kind, put into an oven until thoroughly dry, allow to cool, plant seeds in both, add a definite amount of water to one from time to time, keep the other dry, and keep both in a warm, well-lighted place. Note the germination and growth.

2. **Growth in Different Soils.**—Fill several small flower pots with different kinds of soils and sand, plant with seeds of the same kind, give the same amount of water to each at definite intervals, keep in a warm, well-lighted place. Note time of germination and rate of growth.

3. **Influence of Sand on Rate of Growth.**—Take a supply of rich, loamy soil and a supply of clean sand, fill one flower pot with the soil, a second with three parts soil plus one part sand, a third with two parts soil and two parts sand, a fourth with one part soil plus three parts sand and a fifth with pure sand. Plant the same kind of seeds in all, give the same amount of water from time to time, and keep in a warm, well-lighted place. Note the time of germination and rate of growth.

4. **Temperature Affects Growth.**—Fill two pots with the same kind of good, rich soil and plant with same kind of seeds. Give the same amount of water and keep each in a well-lighted place, but keep one in a warm place (70 degrees F. or more) and the other in a cold place (about 40 degrees F. or less). Note the rate of growth.

5. **Effect of Light on Germination and Growth.**—Fill two flower pots with the same kind of good, rich soil, plant with the same kind of

seeds, give the same amount of water from time to time, keep in a warm room, but keep one in the light and one in the dark (closet or box). Note the time of germination and rate of growth.

QUESTIONS

1. Name the four most important factors in plant growth.
2. Tell of the importance of water in plants.
3. What are the hydrophytes? Give examples.
4. What are the mesophytes? Give examples.
5. What are the xerophytes? Give examples.
6. What are the halophytes?
7. What are the tropophytes?
8. How may plants obtain the nitrogen found in air?
9. What elements are likely to be deficient in some soils?
10. How does temperature affect growth of plants?
11. Tell of the influence of light on plant growth.
12. Make a list of plants that thrive in partial shade.
13. Make a list of common food plants and tell in what part of the United States or of the world they are grown.
14. Same for common fibre plants. Why are they not grown over wider ranges of country?
15. What are some of the geographic influences governing the plant life of a region?

CHAPTER XIII

FORESTRY

THE study of forestry is a branch of botany that has attracted a great deal of attention in recent years. When America was explored and settled by white men, millions of acres were covered with virgin forest. The land was more valuable for cultivation than the forest was for any use that the settlers could make of it. Therefore, enormous quantities of these wonderful forests were cut and burned in the course of settlement. But with the increasing population and decreasing forests, lumber and wood became more and more valuable, until the United States Government found it necessary to set aside large areas of land as forest reserves. These conditions naturally led to the study of forestry, a subject which involves the planting and care of forests and proper protection and economic handling of our natural forest products and the planting and care of shade trees. (Fig. 85.) Many woodland areas have been denuded which are of little or no value for other crops. (Fig. 86.) The United States Government and the various state governments employ a large number of professional foresters for this work, and many cities employ foresters to attend to the planting and care of shade trees. Forestry is now recognized as one of the most important studies in our large institutions of learning. The principles of forestry are also practiced on many individual farms throughout the land.

Although we cannot take a course of forestry in connection with this brief course in botany, we can learn something of the life of the individual trees of which the forest is composed and some general principles of tree growth.

Tree Characteristics.—Trees are not only the largest plants, but they are extremely complex and highly developed. However, each tree must arise from a single cell, in exactly the same manner as any other plant, and is subject to exactly the same laws of plant growth as any other plant. A tree is a woody

Fig. 85.—Modern forestry methods provide for perpetual crops of lumber and other forest products. Forest beetles are held in check by burning the twigs after each harvest. (U. S. D. A.)

plant with a single stem or trunk which may be straight with many side branches or the trunk may divide into subdivisions. It has a well-developed root system which gives it firmness and by which it secures water and mineral foods. It has leaves of size, shape and arrangement peculiar to its species. The flowers of some trees are large and showy while those of others are so small and inconspicuous that many people never see them and

believe that certain species of trees never produce flowers. The fruits are of various kinds and will repay you for careful study.

Trees have definite forms which are characteristic of their species; some trees are low with round dense heads, as the Norway maples, others are tall and open as the elm and plane-tree; some have a single straight shaft as the pine and hickory, while in others the main trunk branches in such a manner as to lose its identity in several subordinate branches.

FIG. 86.—Denuded of forest growth by ruthless cutting and fires. A barren rocky waste is left, unsuited to other agricultural crops. (U. S. D. A.)

Tree Foods.—The tree uses the same kind of food and secures it in the same manner as any other plant (Chapter X), and the amount of energy required in securing the raw food, transferring it throughout the plant, and making it into material of its own is far greater than we can appreciate. Wood is composed primarily of carbon, oxygen and hydrogen. When absolutely dry about one-half its weight is carbon. We have already studied the processes and results obtained in burning wood. (Chapter IX.)

Tree Growths.—We have already learned something of growth (Chapter X) and know the part played by the *cambium.* When we think of the growing tree, we must think of the thin cambium in not only the trunk but in every branch and twig, and in every root and rootlet. (Chapter VIII.) When an annular ring is once formed, its position in the tree is never changed, but new annular rings will be formed, each outside of the preceding one. In most trees the inner wood becomes darker and harder with age and is known as the heart-wood, while the outer which is softer and lighter in color is known as the sap-wood. The passage of water through the heart-wood is checked, but it continues to pass through the sap-wood during the life of the tree. As the tree grows, the amount of heart-wood increases by continual additions from the cambium. Tissues of different woods have peculiar characters by which students can readily recognize them.

Conditions of Growth.—Different species of trees require different conditions for their growth. Some grow in cold climates, others in warm climates; some in dry soils, and others in swamps; some require certain kinds of soil and light exposure. Natural forests are seldom of a single species but of several species which live and grow under the same or similar conditions. Under natural conditions there is a continual struggle between the trees for food, water, and light, and many trees die because other trees near them are more vigorous.

Trees produce great numbers of seeds, but very few of these seeds produce trees. Many of them fall in places where the soil, water or light requirements are unsuited to their existence, or are destroyed by man or some of the lower animals. However, some of them grow where they fall and some of them are carried for long distances, grow and may be the beginning of a new forest area. Some young trees are more vigorous than others of the same kind, grow faster, overtop them and shut

off the light and eventually starve them to death. A few are able to grow beneath the shade of others. Sometimes a forest is so dense that it is difficult for young trees of the same species as the forest to get a start, but other trees of a different species and with different light requirements may become established.

Forest Enemies.—The forest has many enemies; the most destructive is man who may lumber it with great waste, or use it for grazing with great losses to the young growth, or carelessly set fires by which large areas are destroyed.

Insects, fungi, wind storms and snow storms also take heavy toll from these natural resources.

EXERCISES ON FORESTRY

1. **Learn the names** of as many trees as possible on your street, in your town, in the park or in a near-by forest tract.
2. **Collect flowers, seeds and leaves** of as many trees as possible.
3. **Forms of Trees.**—Make a diagram showing the peculiar branching and form of the common trees.
4. **Tree Differences.**—Make studies in the woods or elsewhere and report on what kinds of trees in your vicinity are the tallest and what kinds are the shortest, what ones make the densest shade, what ones endure shade, what are rapid growers and what are slow growers?
5. **Study blocks of different kinds of wood** and learn to recognize them. Carpenters and other wood workers can help you in this study.
6. **Close and Open Plantings.**—Compare the shapes of trees of any species in dense plantings with the same in open places. Explain.

QUESTIONS

1. What uses are made of the lumber trees in your community?
2. What fruit-producing trees are found in the forests of your community?
3. What nut-producing trees are found in the forests of your community?

CHAPTER XIV

PLANT DISEASES

Plants are subject to diseases which are similar in cause and character to those of the animal, except that the majority of animal diseases are caused by bacteria, while the majority of plant diseases are caused by fungi.

A healthy plant is one in which all the parts are performing their regular functions; a plant which is growing and producing fruit in the regular manner. A *disease* is any condition which interferes with the regular functions of the plant or causes its death.

Anything that interferes with the taking of food materials of any kind, with photosynthesis, with the movements of plant fluids, with transpiration, with reproduction or with any other function of the plant is the cause of disease. The disease itself is frequently designated by the name of the causal organism.

Two Groups of Diseases.—Diseases may be conveniently grouped into organic and environmental:

Organic (caused by organisms)

Fungi	Flowering plants	Mites
Bacteria	Insects	Nematodes
Slime moulds		

Environmental (caused by surrounding influences)

Soil	Temperature	Smoke
Moisture	Gas	Chemical (near factories)

Some Symptoms of Disease.—A disease may cause (*a*) discoloration of the foliage or other parts of the plant; (*b*) new or excessive growth; (*c*) wilting; (*d*) unnatural shedding of parts;

(*e*) foliage spots; (*f*) perforation of foliage; (*g*) variegation of foliage; (*h*) dying of leaves and twigs; (*i*) dwarfing or atrophy of parts; (*j*) development of distorted or abnormal growths, such as witches broom, galls, corky out-growths, etc.; (*k*) cankers; (*l*) increase in size or modification of parts; (*m*) curling of foliage and formation of rosettes; (*n*) hairy roots; (*o*) exudation (gums, resins); (*p*) sun burns; (*q*) rot of fruits, stems or roots.

The most noticeable diseases of plants are the *rots* of fruits and stems which are usually caused by fungi and bacteria; *blights* of the leaves, stems, flowers and fruits, which are also caused by bacteria and fungi; *spots* on leaves and fruits, which are caused by both fungi and bacteria; *mildews,* which are white powdery fungous growths on leaves, twigs and fruits; *smuts* and *rusts,* which are fungous diseases of grains and other plants: *cankers,* which may be due to fungi or other causes; *yellowings, mosaics,* and other discolorations, which may be due to any one of many causes.

Wilts.—When the disease injures or destroys the root system, the food and water supply from soil is reduced or cut off and the plant is either weakened or killed. Diseases of the stem may have the same effect. Diseases of the foliage may interfere with the absorption of carbon dioxide, the transpiration of water and the photosynthesis of the plant.

The wilt diseases are usually due to fungi or bacteria which live in the tracheary tissue of the fibro-vascular bundles and thus interfere with the rise of water. These diseases are especially injurious on herbaceous plants. The fact that the organisms live within the plant make it impossible to treat by means of spraying. Many of these wilt organisms live in the soil from year to year and cannot be controlled except by crop rotation in which it is necessary to use crops which are not subject to the disease in question.

Root Diseases.—*The crown gall* (Fig. 87) is one of the very common diseases of our fruit and other trees, roses, berries and many other plants. It is caused by bacteria and appears as abnormal growths on the roots and sometimes on the trunk and

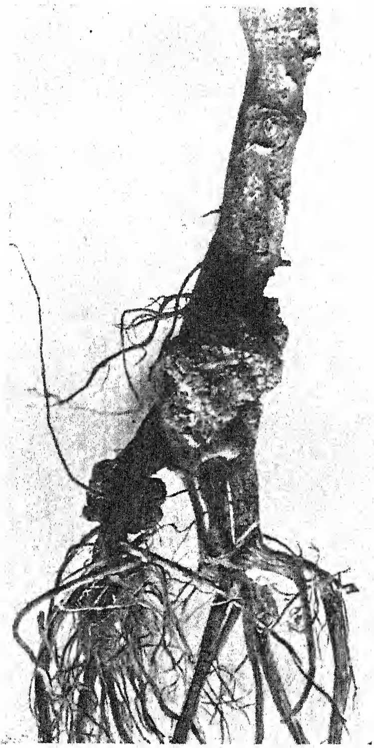


FIG. 87.—Young tree with crown gall.

branches. In some cases it does but little harm, but in other cases it reduces the vitality of the plants and in extreme cases causes death. The so-called hairy root of the apple, pear and quince is caused by the same organism. The roots of these dis-

eased trees are covered with numerous small roots which are usually associated with small galls. There is no known treatment for this disease. Diseased trees should not be planted.

Galls or knots on the roots of plants may be due to other causes. Among the most common are the galls on the roots of apples and grapes which are caused by insects; abnormal growths

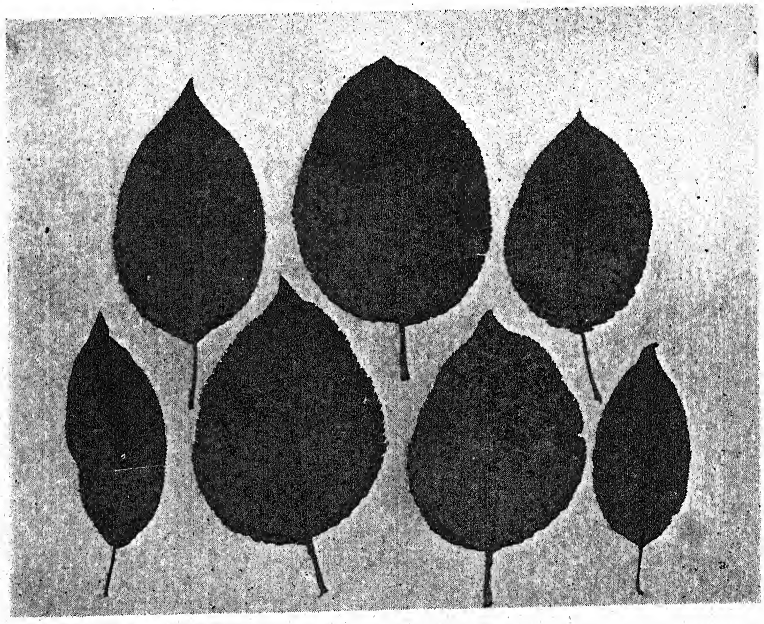


FIG. 88.—Leaf spot disease of the pear.

on the roots of cabbage and related plants due to slime moulds; and knots on many plants due to minute worms (nematodes). These and many other diseases of the root systems of plants interfere with nutrition, dwarf the plants, reduce the crop and frequently cause death.

The leaf diseases are mostly due to fungi which cause leaf spots, leaf curls, blights, wilting, dying and droppings. One of

dles of the spermatophytes, but the stem is strengthened by the masses of schlerenchyma tissue which can be readily seen.

The leaves or fronds, as they are usually called, are very similar in structure to the leaves of the Angiosperm. In fact, the similarity is so striking that it is not necessary to describe it at this time, but the student will do well to make a careful study and comparison of the leaf with that of the Angiosperm.

FIG. 97.—A fern glade.

(Chapter IV.) However, the leaves tend to unroll in a peculiar manner (Fig. 98) which can be readily seen and which is characteristic of the ferns.

Fruit Dots.—On the under surfaces of many of the older leaves will be found numerous fruit dots or *sori* (singular sorus). (Fig. 99 and 100.) They vary greatly in size, character and arrangement in the different species of ferns and in most cases are covered with a delicate membrane known as the *indusium.*

(Fig. 100.) These dots contain numerous *sporangia* (singular sporangium) (Fig. 101), which are filled with spores. Each sporangium is supported by a stalk and from a side view appears to be flat, but as a matter of fact is slightly thicker in the centre than on the margin. The marginal cells are highly specialized and are of two kinds; the thick-walled cells from about three-fourths of the distance and the thin-walled cells for the remainder of the distance. When the spores (Fig. 102) are mature, the drying out of the sporangia results in an uneven

FIG. 98.

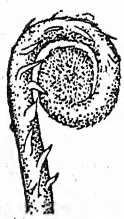


FIG. 99.

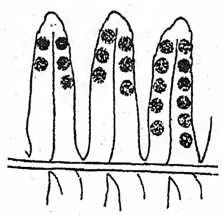


FIG. 100.

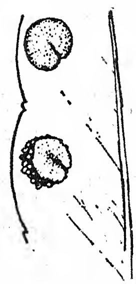


FIG. 101.

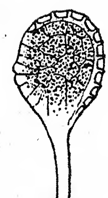


FIG. 102.

FIG. 98.—Young fern leaf showing method of unrolling.
FIG. 99.—Part of fern leaf showing sori or fruit clusters.
FIG. 100.—Part of fern leaf showing sori with indusium.
FIG. 101.—Sporangium from fern sorus.
FIG. 102.—Fern spores from sporangium.

tension of the two kinds of cells, a bursting of the sporangium and a scattering of the spores.

Two Steps in Reproduction.—The spores germinate and eventually form what is known as the *prothallium.* (Fig. 103, *e.*) In most ferns this prothallium is very small and somewhat heartshaped. It is composed of chlorophyll bearing parenchyma cells and has many rhizoids which are very similar to the root-hairs of the higher plants. They penetrate the moist soil from which they derive both water and food in the same manner as root-hairs. On the under surface will be found numerous small bodies, the *archegonia* (singular *archegonium*) and the

antheridia (singular *antheridium*). In some ferns they are borne on the same prothallus while on others they are borne on different prothallia.

The Archegonia (Fig. 103, *b''*) are borne near the notch of the prothallus, and somewhat flask-shaped with the base imbedded in the tissues and the neck extending downward and slightly curved. An examination with the compound microscope shows a large egg (ovum) or female cell (Fig. 103, *c''*) in the large part and a row of canal cells in the neck. These canal cells become gelatinous or semi-fluid in character.

The Antheridia (Fig. 103, *b'*) are spherical and produce great numbers of minute, unicellular, spiral, free swimming bodies known as *sperms* or male cells. (Fig. 103, *c'*.) The sperm cells swim in the moisture on the surface of the prothallia and the soil, and some few eventually reach the archegonia, enter the canal and one unites with each *ovum* or egg cell. This is known as *fertilization*. It corresponds to the fertilization of the egg in the embryo sac of the Angiosperm. (Chapter VI.) As a result of this fertilization, cell division occurs and the egg grows into a fully developed fern. (Fig. 103, *e, f*.) With the development of the fern, the prothallus, upon which it at first feeds, is gradually destroyed.

Horse Tails.—There are many other fern-like plants which we will find quite interesting if we have time to study them. Among the most common are the horse-tails or scouring rushes (*Equisetum*). The aërial stems are derived from an underground stem and may be branched or unbranched, hollow jointed, fluted with well-marked longitudinal ridges and furrows and infiltrated with silica which makes them rough and rigid. The branches and modified leaves are always in whorls and at the nodes. At each node the stem is surrounded with membranous sheaths which correspond to the leaves of higher plants. A cone-shaped fruiting structure is borne at the apex of the stem

11

and is composed of modified leaves or *Sporophylls,* bearing small sacs or sporangia containing the spores. The spores have four spiral rings which straighten out when dry and roll up when wet and thus cause the spore to move over short distances. The

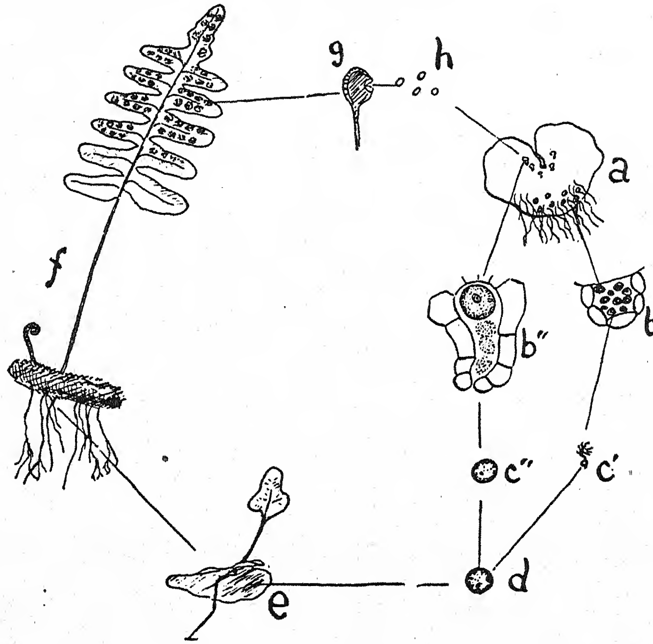


Fig. 103.—Diagrammatic representation of the life history of the fern: a, prothallium; b′, antheridium; b″, archegonium; c′, sperm; c″, ovum; d, oöspore; e, prothallus and young fern; f, mature fern showing under-ground stem, root and leaf bearing sori; g, sporangium; h, spores.

life history of the horse tail is practically the same as that of the true fern.

Other Fern-like Plants.—The so-called club mosses or ground pines, the selaginellas and the quillwort are groups of small plants which have life histories very similar to that of the true ferns.

The greatest value of the ferns at the present time lies in their great beauty for decorations of various kinds and we must

not forget that the growing of ferns is an industry representing many thousands of dollars. In past ages the ferns were much more abundant and much larger than at the present time and we are indebted to them, to some extent, for the enormous beds of coal from which we secure most of our supply of fuel. (Chapters IX and XVIII.)

EXERCISES WITH PTERIDOPHYTES

1. **Examine a fern** carefully and note its roots, stem, leaves, sori and indusium.

2. **Cut cross-sections** of the stem and examine under a compound microscope and note the points referred to in the text. Material for this purpose can be preserved in alcohol or formaldehyde.

3. **Study the leaf** in the same manner as indicated for leaf of the Angiosperm. (Chapter IV.)

4. **Remove a sorus,** crush and examine under the compound microscope. Note the character of the sporangia as referred to in the text.

5. **Examine a prothallus** with a hand lens or under a low power of the compound microscope. Material for this purpose can usually be secured from a neighboring greenhouse.

QUESTIONS

1. Where do you find the stems of the fern?
2. Compare the fern stem with the stems of a flowering plant.
3. Compare the leaf of a fern with the leaf of a flowering plant.
4. What do you find on the fern leaf not found on the ordinary leaf?

Reference.—Read all you can about the formation of coal-beds. For such information see a good encyclopedia and works on Geology.

CHAPTER XVIII

BRYOPHYTES

We will now study the two great groups of *Bryophytes,* the *Musci* or mosses and the *Hepaticæ* or liverworts. They are of little value at the present time except for packing material where it is necessary to retain moisture, but in past ages (the Carboniferous Age) they were much more abundant than at any time since and we are indebted to them for the greater part of our enormous beds of coal which we are now using.

Mosses.—An ordinary moss plant presents an upright stem with three more or less distinct rows of leaves. A more careful examination will show us that this stem is very weak, that it does not contain a fibro-vascular bundle but is composed of elongated parenchyma cells. We will find also that the leaves are composed entirely of parenchyma cells and that their apparent mid-rib is composed of elongated cells. These characteristics very readily convince us that we are studying a very simple type of plant as compared with the Pteridophytes and Spermatophytes.

Arising from the top of this plant is a long, slender stem, *setea,* bearing a *capsule* which is covered with a cap or *calyptra.* (Fig. 104, *a, b.*) If we remove this cap we will find the *operculum* (Fig. 104, *c*), which is a small cover on the end of the capsule. If we remove the operculum (Fig. 104, *e*) we will find the *peristome* or teeth (Fig. 104, *d.*) These teeth are very sensitive to varying degrees of moisture which causes them to move inward and outward and thus controls the distribution of the spores which are borne within the capsule. These spores will grow and each produce a filamentous *prothallus* or *protonema* which gives rise to new moss plants.

But moss plants also have sexual organs similar to the ferns. They are borne in the tops of the leafy plants early in the spring and are known as *antheridia* and *archegonia*. (Fig. 104, *f*, *g*.) The antheridia are club-shaped and have very long necks. The

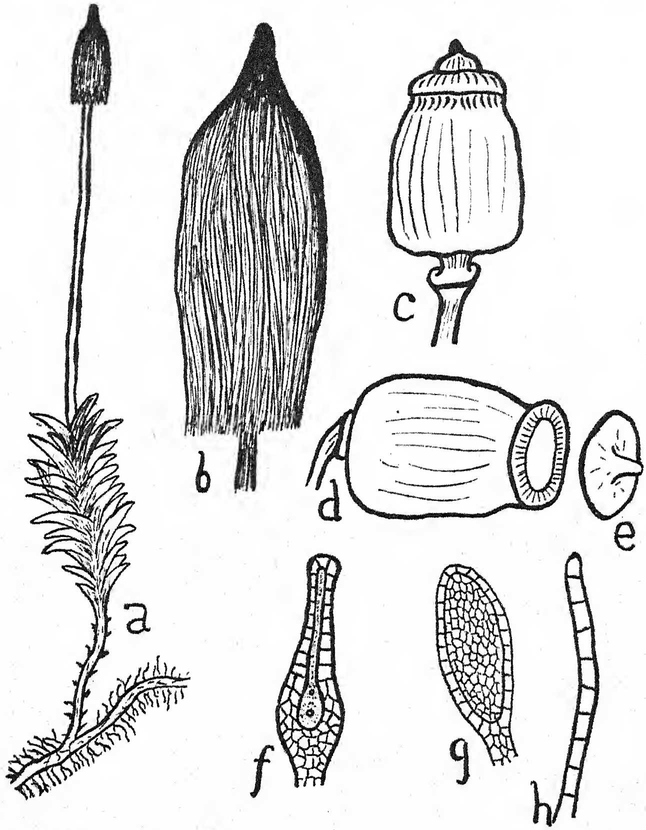


FIG. 104.—a, mature moss plant; b, capsule covered with calyptra; c, capsule without calyptra; d, capsule with operculum removed showing peristome; e, operculum; f, archegonium; g, antheridium; h, paraphyses or sterile organ.

antheridia and archegonia are always borne on different plants. The process of fertilization is practically the same as in the ferns and the fertilized egg grows into the seteæ and capsule referred to above.

There are two large groups of mosses, the *Bryales,* which we have just described and the *Sphagnales.* This latter group is the characteristic moss of the sphagnum swamps and was the most important group of plants in the formation of peat and coal beds.

The Hepaticæ or liverworts are not so familiar to most of us as are the mosses and ferns. They rank next below the mosses and are an extremely interesting group for study, but of very little, if any, economic value. There are several divisions of the hepaticæ, but one of the largest and most common forms

Fig. 105

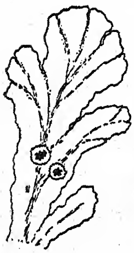


Fig. 106

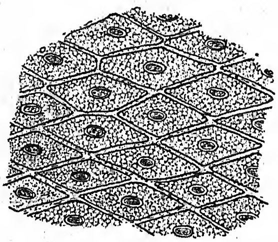


Fig. 107

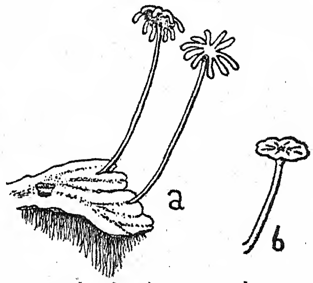


Fig. 105—Marchantia polymorpha showing two cupules bearing gemmule.
Fig. 106.—Surface view of marchantia polymorpha very much magnified.
Fig. 107.—a, female plant of marchantia polymorpha bearing two archegonial branches; b, also a single antheridial branch from a male plant.

is known as *Marchantia polymorpha.* (Fig. 105.) It reminds us of the fern prothallus but is much larger and branching. It is thick along its central axis and thin at the edges, lies flat on the wet soil and has many rhizoids. The upper surface is divided into small areas with a small opening (stoma) (Fig. 106) in the centre of each. These small areas give it a superficial resemblance to the liver of an animal and therefore the name "liverwort." As the apical part of the plant grows the basal part is gradually dying. Along the upper surface will frequently be found saucer-shaped structures containing small buds which are capable of growing into new plants; a non-sexual method of reproduction.

If we examine a cross-section of the thallus under a compound microscope we will find the epidermis covering a large chamber beneath each stomata. Within the chamber are great numbers of delicate chlorophyll bearing parenchyma cells while the lower cells contain little or no chlorophyll.

The sexual organs are borne on separate plants. The female

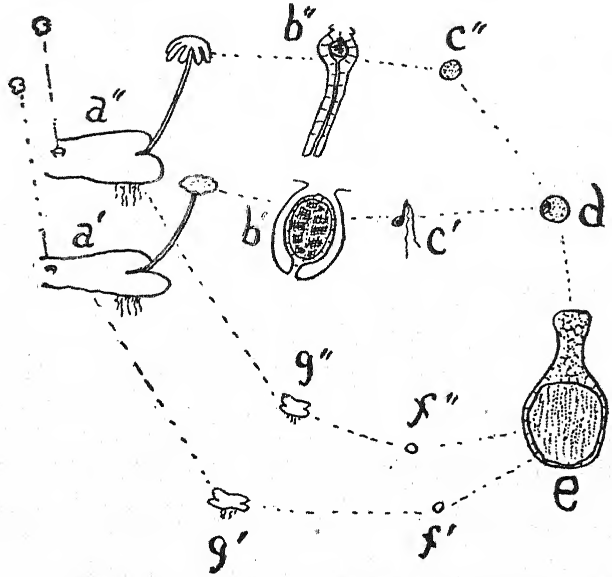


FIG. 108.—Diagrammatic representation of the life cycle of Marchantia polymorpha; a′, mature male plant; a″, mature female plant; b′ antheridium; b″ archegonium; c′, sperm; c″, ovum; d, oöspore; e, young sporoplyte; f′, and f″, spores; g′, and g″, young plants.

plants (Fig. 107, *a*) bear erect stalks supporting radiating structures which resemble the handle and ribs of an umbrella in their arrangement. On the under surface of the radiating parts will be found the minute flask-shaped *archegonia.* The male plants (Fig. 107, *b*) bear erect stalks supporting disk-shaped bodies, on the upper surface of which will be found minute openings into cavities containing the *antheridia.* The fertilization is the same as in the ferns and mosses. The stalk of the female

body elongates and numerous *capsules are produced* on the under surface. These capsules contain numerous spores and also some spiral-shaped bodies known as *elaters,* which burst the capsules and help to distribute the spores. The *spores* grow and produce new plants. (Fig. 108.)

There are many other forms of liverworts, some of which are leafy and resemble moss plants, and are frequently mistaken for mosses.

EXERCISES WITH BRYOPHYTES

1. **Examine a moss plant** and note the character of its stem and leaves.

2. **Examine a fruiting moss plant** and note the setea, capsule, and calyptra. Remove the calyptra and examine with a hand lens for the peristome.

3. **Examine a non-fruiting plant** of the *Marchantia polymorpha* and note shape, surface area, stomata, and cupules or non-sexual fruiting cups. Scrape some of the rhizoids from the under surface and examine under the compound microscope.

4. **Cut a cross-section** and examine under a compound microscope and note different types of parenchyma cells.

5. Examine the plants which are carrying the fruiting bodies.

6. **Crush a capsule** and examine under the microscope; note spores and elaters.

QUESTIONS

1. To what great group do the mosses and liverworts belong?
2. Describe a true moss plant.
3. Describe the thallus of the liverworts.
4. How and where are the sexual organs of the liverwort borne? How does the fertilization take place?
5. What are the most striking points learned in your study of Bryophytes?

CHAPTER XIX

THALLOPHYTES

WE HAVE now come to the lowest great division of the plant kingdom, the *Thallophytes,* which are subdivided into three divisions, the *Algæ,* the *Fungi* and the *Bacteria.* The second and third of these groups do not contain chlorophyll and are therefore quite different in habit from all other groups of the plant kingdom.

The algæ vary greatly in both size, structure and color, but all of them contain chlorophyll and are able to do the work of photosynthesis or starch-making. The range from the small, one-celled plant which cannot be seen without the aid of the microscope, through delicate thread-like forms up to the enormous sea-weeds, possessing root-like, stem-like and leaf-like organs. They are widely distributed throughout the world and are of much greater importance than we might at first suppose. Minute forms are found in great numbers, causing the green stain on the bark of trees and stones and brick walls, in the streams and pools, and in the seas, gulfs and bays and even the broad ocean itself.

The types are entirely too numerous to mention in a work of this kind, and therefore, we must content ourselves with a study of two or three of the most common forms. Many of the unicellular forms found in moist places on trees and walls reproduce by simple division, each division resulting in the formation of two new plants, each similar to the parent. Each plant is capable of performing all the function of a much larger and more complex plant; *i.e.,* the absorption of water and minerals in solution and of nitrogen, the taking in of carbon dioxide, and photosynthesis and reproduction.

The filamentous forms are composed of single rows of cells, each cell capable of sub-division, and if separated from the others, of producing a new plant. The very common Spirogyra (Fig. 109) is an excellent type for study. The cells are cylindrical in shape and attached end-to-end. Each cell contains an inner lining of protoplasm and numerous cross strands of the same material; also a nucleus which may be located in any part of the cell but usually in the centre. The protoplasm and nucleus are transparent and cannot be seen readily without the

FIG. 109.

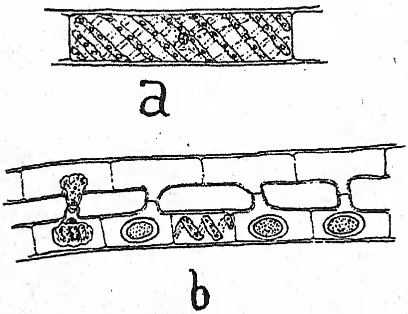


FIG. 110.

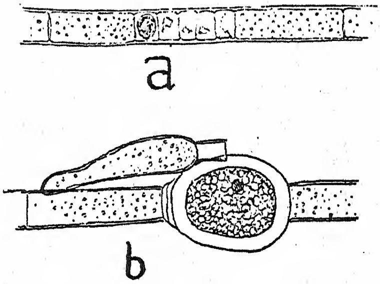


FIG. 109.—Spriogyra: a, single cell showing chromatophore and nucleus; b, two plants showing sexual reproduction.
FIG. 110.—Œdogonium: a, plant showing non-sexual cells; b, plant showing oögonium and antheridium.

use of an artificial stain. The spaces between the strands of protoplasm are known as *vacuoles* and are filled with water. Embedded in this protoplasm will be readily seen the spiral *chromatophores* or *chloroplasts* containing the *chlorophyll*. Scattered along this chlorophyll will be seen the round shining *pyrenoids* which are supposed to be the centres for food formation or photosynthesis. The cell of the spirogyra may be looked upon as a typical plant cell in which all the functions of plant life are performed.

Spirogyra.—If we examine a great many plants of spirogyra we will probably find some specimens which are attached

two-and-two by means of short tubes, the one plant being male and the other female. The tubes are outgrowths from both plants which tend to unite; the separating walls are dissolved and the contents of the male cells pass into and unite with the contents of the female cells, forming what is known as *zygospores,* which will eventually produce new plants.

Ulothrix is another filamentous form which produces a large number of ciliated free-swimming cells known as *zoöspores.* They swim for a time, come to rest and each grows into a new plant. In some cases these free-swimming cells (gametes) unite in pairs and form *zygospores.*

Œdogonium (Fig. 110) is another filamentous form, a species which presents a great variation in sexual character. A cell may produce a single large, ciliated cell or zoöspore which will swim for a time, attach itself and grow into a new plant. Or, it may produce a large female cell (gamete) which is retained in the old cell-wall (oögonium) and fertilized by small free-swimming zoöspores or sperms (gametes) which are produced by another cell or antheridium. In other species of Œdogonium the oögonia are produced in large female plants and the antheridia in the small male plants.

The Vaucheria are filamentous but unicellular and multinuclear forms. The non-sexual reproduction is by the formation of a cross wall at the end of a filament, thus forming a cell from which a single large motile or non-motile spore is produced. The sexual reproduction is by the formation of oval oögonia, each containing a single large ovum or egg and curved, tubular *antheridium* containing many small *sperms.* The sperm escape and at last one reaches the ovum which is fertilized and results in an oöspore or resting spore. This is more nearly like the liverworts, mosses and ferns than most of the algæ.

Other Algæ.—Concerning the many other forms of algæ, we may briefly say that they are the forests and the pastures of

the waters and without them animal life in the water would be as impossible as animal life on the land without land plants. We may also add that some articles of commerce, such as iodine, are obtained from the algæ, and the time may not be far distant when the enormous beds of seaweeds will prove a valuable source of commercial potash for fertilizers.

The fungi are surprisingly like the algæ, but differ from them in the fact that they do not possess chlorophyll. Therefore, they are unable to do the work of photosynthesis and must depend primarily upon organic matter, *i.e.,* either dead or living plants or animals, for their food supply. Those which live on dead organic material are *saprophytes* and those which live on living organisms are *parasites.* We will give brief descriptions of the most common types.

The yeast plants (*Saccharomyces*) are among the very simplest in structure. They are very minute, spherical, and reproduce by budding. They are found abundantly in sugary solutions and are extremely important in alcoholic fermentations. We are all familiar with their use in the making of bread. Although simple in structure they have a method of reproduction which takes them from the lowest of the fungi.

The common bread mould (*Rhizopus nigricans*) (Fig. 111) is one of the best known of the lower fungi. It occurs on stale bread kept in damp places and appears as numerous delicate, white threads containing protoplasm, both in the bread and erect on the surface. These threads are called *mycelium,* but a single one is often called the *hypha.* On the tips of the hyphæ are numerous spherical sporangia or spore cases containing spores. They become black with age, burst and discharge the spores which are readily carried in the air.

The sexual reproduction is by the formation of lateral branches from two filaments. These branches come in contact and swell, a cell-wall is formed across each and the wall at

the point of union is dissolved, permitting the union of the contents of the two cells. This results in the formation of the zygospore which is capable of giving rise to a new plant. The sexual method of reproduction rarely occurs in nature.

The species of Saprolegnia (Fig. 112) are parasitic on fish, but will grow on floating dead flies and other insects and occasionally on decaying food. Thread-like filaments of the fungus grow out from the material on which it is living. Cross walls or septa are formed in these filaments and great numbers of

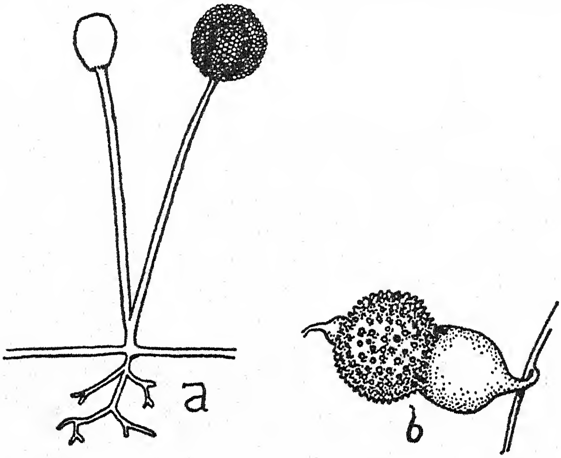


Fig. 111.—Rhizopus nigricans or bread mould; a, entire plant showing sporangia; b, mature zygospore.

unicellular, free-swimming zoöspores will be produced in the apical cell. These zoöspores escape, swim for a time, become attached to suitable food material and produce new plants. Certain of the filaments will also produce antheridia and oögonia, giving rise to oöspores, but there is some doubt as to whether fertilization really occurs.

Parasitic Fungi.—The downy mildews, powdery mildews, and many other fungi are parasitic on the higher plants and are causes of heavy losses to our agricultural interests every year.

Among the most interesting of these parasitic fungi are the rusts and smuts, some of which are very destructive to our grain crops. Some of the rusts have the peculiar habit of requiring two distinct host plants in order to complete their life cycle. In such cases they have two or more stages, one occurring on one host and the other on the other host; the spores in each case will, as a rule, grow only on the opposite host plant.

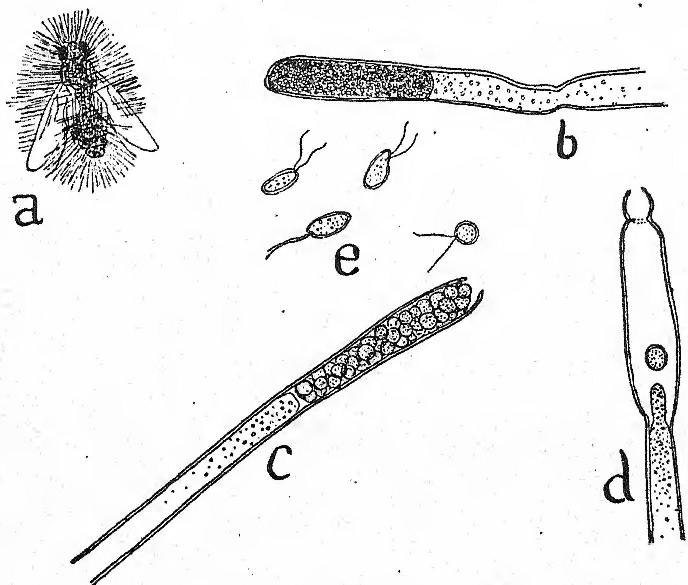


FIG. 112.—Saprolegnia. a, infested fly; b, immature sporangium; c, mature sporangium; d, same after the escape of the spores; e, free swimming spores.

The fleshy fungi (Fig. 113), many of which are spoken of as mushrooms, and toad-stools, usually grow either parasitically or saprophytically on woody plants. Some are umbrella-shaped, while others are shelving in character and still others are the well-known puff-balls.

The stipe or stem of the mushroom usually rests in a *volva* or cup. The stipe supports the pileus, or cap, on the under side

of which we find the gills or lamellæ on the surface of which the spores are borne. We frequently speak of fungi as growing very rapidly because of their sudden appearance in a fully developed form. However, the growth is not nearly so rapid as it appears. The mycelium may grow slowly and for many months in the tissues of the host plant, which it is slowly eating

FIG. 113.—Two specimens of mushrooms. The one on the left shows the annular or ring.

away, and finally come to the surface and form the *sporophores* or fruiting bodies, with which we are familiar, in a very few hours. Some few fungi are used for food, but many of them are deadly poison and the inexperienced person will do well to refuse all forms except the strictly fresh puff-balls.

Our greatest interest in the fungi lies in the fact that so many of them are parasitic on our farm crops and cause the loss

of many millions of dollars every year. This loss is so enormous that a new branch of botany, known as plant pathology, has been developed for the study of plant diseases and methods for their control.

EXERCISES WITH THALLOPHYTES

1. **Examine algæ,** as many as circumstances will permit, and note the points referred to in the text. The algæ may be collected from small streams and kept in jars and dishes on the laboratory tables for many days and studied with the aid of the compound microscope.

2. **Collect many specimens** of parasitic fungi found on leaves and fruits of plants, especially on cultivated plants. Study them in their different stages of reproduction.

3. **Develop yeast** in a weak solution of water and sugar and study specimens under the microscope.

4. **Keep some moistened bread** in a warm chamber (*i. e.*, under an inverted jar or in a closed dish). When mould has developed study its different stages.

5. **Keep some dead flies** in an open bottle of water and watch for the development of *Saprolegnia;* then make a microscopic study of it.

QUESTIONS

1. What three groups are included in the Thallophytes?
2. In what respect do all the algæ resemble each other?
3. Describe reproduction in unicellular algæ.
4. Describe reproduction in Spirogyra.
5. Describe reproduction in Ulothrix.
6. Describe the forms of reproduction in Oedogonium.
7. How is reproduction accomplished in Vaucheria?
8. Tell of the economic value of algæ.
9. How do the fungi differ from algæ?
10. Describe the structure of yeast plants.
11. What is the structure of bread mould? Tell of its reproduction.
12. Give examples of parasitic fungi. Of what importance are they?
13. Tell what you can of the fleshy fungi.

Reference.—Read accounts of algæ and of fungi, found in an encyclopedia and special books on these subjects.

CHAPTER XX

BACTERIA

Bacteria are the smallest of all plants and in fact some of them are the smallest known organisms. It would require 125,000 of the smaller ones, placed side by side, to make a line one inch long. They are like the fungi in that they do not contain chlorophyll and cannot perform the work of photosynthesis. Therefore, they are either saprophytic or parasitic. Some are motile and others non-motile. They multiply by simple cell division and many species form resting spores which enable them to resist extremes of temperature and humidity.

Abundance.—Bacteria are more abundant than other forms of life. They float in the air that we breathe, are in the water that we drink and the food that we eat. They are to be found in our mouths, lungs, stomach, and intestines. They cause the souring of milk, the fermentation of various liquids, the decay of fruits, vegetables and meats. Fortunately the great majority are harmless and many are beneficial. Among the most interesting of the beneficial species are those which are involved in the fixation of nitrogen. (Page 117.)

Causes of Disease.—However, many bacteria are the causes of diseases of both plants and animals. Among the most serious of plant diseases caused by bacteria are the fire blight of the pear and apple, the black rot of cabbage and related plants and the root or crown gall of our fruit trees and many other plants. Many serious animal diseases are caused by bacteria such as tuberculosis or consumption, diphtheria, tetanus or lockjaw, grippe, anthrax, cholera and many others which attack man and the lower animals.

With our increasing knowledge of these diseases we are learning to combat them. We are learning how to cure patients suffering from them and also how to prevent them. It is an old saying that "an ounce of prevention is worth a pound of cure," and we are learning that proper sanitation, the removal of filth in which the bacteria breed, the protection of drinking water, the destruction of flies, mosquitoes and other insects that carry bacteria, and personal cleanliness are great helps in the prevention of bacterial diseases.

The study of bacteria has resulted in the development of a branch of applied botany known as *bacteriology* which is receiving a great deal of attention, especially in our Universities and Medical Colleges.

The Myxomycetes (Mycetozoa) or Slime Mounds.—These are forms of life which possess both plant and animal characteristics. They are truly on the border between the plant and animal kingdoms. They are found in the water or on wet soil or decaying vegetables as naked slimy masses of protoplasm, called *plasmodia*. They move very slowly by a peculiar creeping movement similar to that of the *amœba,* which is one of the lowest forms of animal life. This plasmodium has the characteristics of the species to which it belongs and finally produces great numbers of spores, similar to those of some of the fungi. These spores eventually give rise to minute one-celled amœboid individuals which unite to form a new and growing plasmodium. One species of this group (*Plasmodiophora brassicæ*) is the cause of the very common and serious club root disease of cabbage.

EXERCISES WITH BACTERIA.

1. Put a few small shreds of meat into two flasks of water. Boil both for thirty minutes or more; plug one with cotton immediately; leave the other open and set both away for a few days. Examine them from time to time and note differences in their appearance. When they show very

noticeable differences examine a drop of each under the compound microscope. What do you see? What has caused the difference?

QUESTIONS

1. What can you say of the importance and abundance of bacteria?
2. What plant diseases are caused by bacteria?
3. Tell of the character and occurrence of the slime moulds.
4. Why do canned fruits and vegetables keep? Why do they occasionally spoil?

PART II

MOST IMPORTANT FAMILIES OF ECONOMIC PLANTS, WITH SPECIAL EXERCISES

CHAPTER XXI

IMPORTANT FAMILIES OF PLANTS

First Uses of Plants by Man.—The origin and development of agriculture are veiled in the mystery and tradition of the early civilization of the human race. The early historical records are incomplete and no one knows just when the different races began the practice of agricultural methods. Traditions connected with some plants tell us that they were introduced by gods or by kings. It may be that the introduction of some plants date from the reign of certain great monarchs, but in most cases these traditions are of doubtful value.

It is very probable that most, if not all, races of people were more interested in war, hunting and fishing than in agriculture, and that under these circumstances the beginnings of agriculture must have been feeble, interrupted and obscure. The destruction and abandonment of growing crops by war or in the search of better hunting grounds was not conducive to the advancement of agriculture.

Early agriculture must have developed very slowly, and as a result of necessity, or because it made life easier for the individual and the tribe. These early beginnings probably originated in the gathering and storing of wild crops, followed first by a protecting of these wild crops from the ravages of wild animals and other tribes, then by the increasing of their range by scattering seeds, and finally by cultivation. This last step very naturally led to improvements in methods and the selection of the most valuable plants.

Our earliest records of agriculture concern Egypt and China, but it is very likely that agriculture was practiced in India and other parts of Asia as early as in China. There was

also a very ancient agriculture in parts of America, but it is very doubtful if it is as old as the eastern agriculture.

Mankind very naturally began to cultivate those plants which they had previously used from the wild and the practice very naturally tended to discourage their nomadic habits. Increasing population very naturally made greater and greater demands on agriculture and resulted in improved methods, the selection of the best plants and the introduction of new plants.

Westward Movements.—But man could not give up his old nomadic habits quickly. His love for the chase, for travel and exploration, for war and conquest were strong and must be satisfied by actual experiences. Therefore, we see certain great movements of the human race, such as the migrations of the early Christians from Judea westward, the Crusaders from Europe back to the Holy Land and their return to Europe, the discovery, conquest and settlement of America. These and many other similar movements of greater or less proportions very naturally resulted in the introduction of many new and valuable plants into countries in which they were previously unknown.

The history and origin of our agricultural plants is obscure and in some cases the confusion is increased by the names which many of the plants bear. The English walnut is from Persia and not England, the Irish potato is from Peru and Equador and not Ireland, the peach (*Prunus persica*) is from China, but went into Europe by way of Persia.

A knowledge of our most important cultivated plants would be well worth while and very interesting. It is of much greater importance than a knowledge of wild flowers, although this line of work should not be neglected. All of our cultivated plants were originally wild plants, and in recent years many of these so-called "wild plants," such as alfalfa and sweet clover, have been brought under cultivation. Useful plants of our own part of the world may be of very little value in other parts.

IMPORTANT ECONOMIC FAMILIES OF PLANTS

Students should familiarize themselves, in so far as possible, with representative plants in the following families, by studying the living plants where possible, and by giving special attention to their commercial importance. Most of these families are represented by plants which are common to our farms; the fruits of others can be secured on the local markets; and the historical accounts and commercial uses will furnish important lines of study. The studies of these families may be supplemented by others that are convenient or of local importance.

MUSTARD FAMILY (CRUCIFERÆ)

The flowers of this family are usually borne in terminal racemes; usually white or yellow; four petals; four sepals arranged in form of a cross; four long and two short stamens and two stigmas on a single, two-chambered, many-seeded ovary. The plants are mostly herbaceous, sometimes woody, with cylindrical or angular stems and with a pungent, watery juice. The leaves are simple, usually alternate, entire, lobed or bisected and without stipules. The fruit is long, slender and pod-like. None of these plants are poisonous. Many members of this family of plants are very useful as vegetables, forage crops and in medicines. Let us consider a few of the most common and important.

Cabbage (*Brassica oleraceæ* L.) (Fig. 114).—This well-known plant is derived from a wild plant in the south of England and other parts of western Europe. It is perennial, producing yellow flowers and abundant seeds the second year. Plants selected for seed are put in trenches and covered with soil for the winter. They are reset the following spring, bloom and produce seed abundantly. Cabbage seed growing is a well-

developed industry in some parts of the country. It is not known when the cabbage was first used as food. It is referred to in literature antedating the Christian Era by about three hundred years, and it is now very generally used throughout the world.

There are many important commercial varieties. These may be classified into (*a*) the early or short-season group, with

FIG. 114.—The spherical form of cabbage.

small round or pointed heads, as Jersey Wakefield; (*b*) the late or long-season group, with large round or flat heads, as Drumhead and Flat Dutch. All endure spring and fall frosts.

Cauliflower (Fig. 115), Brussels sprouts, Kale and Kohl-rabi (Fig. 116) are derived from the same wild plant.

Mustards (*B. alba* Gray and *B. nigra* Koch).—These well-known plants are annuals and produce seeds of considerable com-

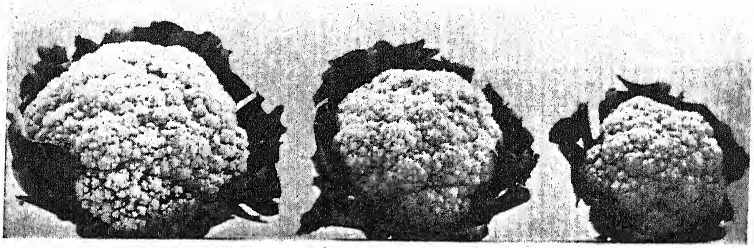


FIG. 115.—Cauliflower, with outer leaves trimmed.

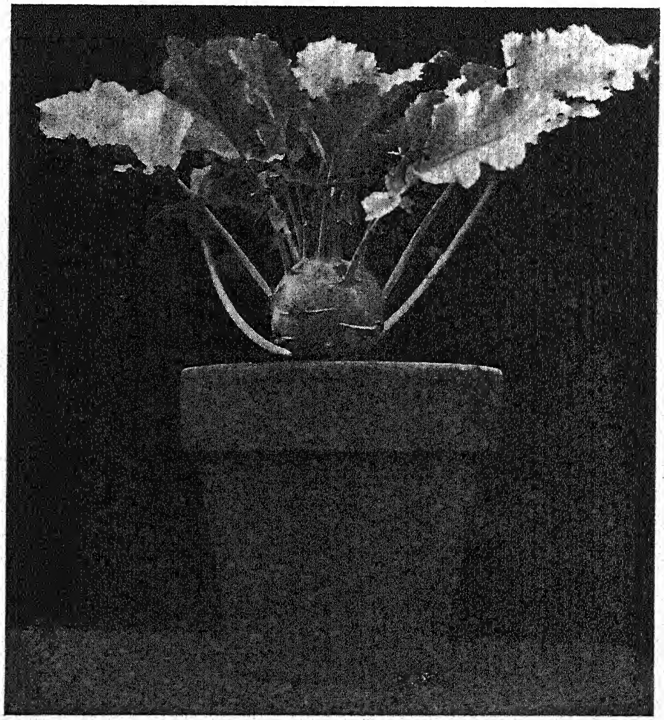


FIG. 116.—Kohl rabi of edible size.

mercial importance. They are used in the preparation of foods and also as medicines. Their use antedates the Christian Era.

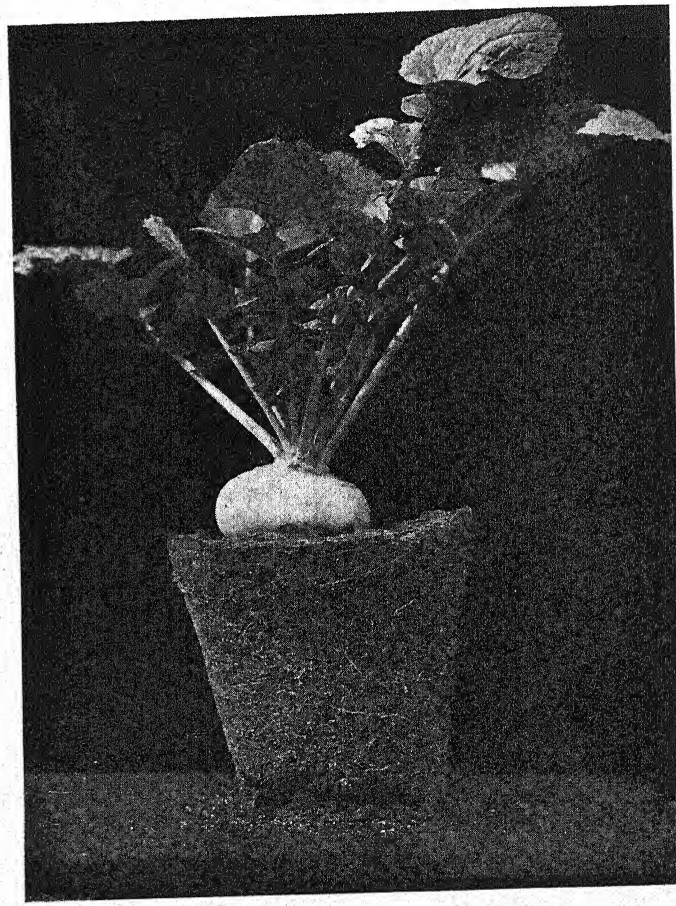


FIG. 117.—The flat form of true turnip with white flesh.

Field Turnips (*B. campestris*) and true turnips (*B. rapa*) (Fig. 117) are well known plants used for food for both man and beast. They originated in northern Europe and Asia and

their use also antedates the Christian Era, but they were not grown extensively until early in the seventeenth century. Seed turnips are also kept and grown the second season in the same manner as the cabbage.

There are several types and varieties of the true or flat turnips. Those with white flesh are most popular, but the yellow-fleshed sorts are also grown. The field turnip, or rutabaga, has yellowish flesh and is rich in flavor. They produce heavier yields than other turnips.

The radish (*Raphanus sativus*), the horseradish (*Cochlearia armoracia*), the rape (*Brassica napa*), and the water cress (*Nasturtium officinale*) and many other valuable plants belong to this family. Most of them originated in the temperate regions of Europe and Asia, and their use and cultivation dates back to a very early period in history.

All of these plants are grown from the seeds which are usually sown direct in the soil in which they are to be grown. The water cress is usually started by transplanting from one locality to another. The mustards frequently escape cultivation and become troublesome weeds. This family also includes wild radish, field cress and many other weeds which are more or less troublesome. However, most of them are annuals or biennials and can be controlled by using a crop requiring frequent cultivation or if growing in wheat or oats by spraying with sulphate of iron.

VIOLET FAMILY (VIOLACEÆ)

Flowers perfect, irregular, axillary, usually solitary, two bracts at base or near the middle of each pedicel. Five sepals which are usually free and persistent; five petals which are hypogynous and alternate with the sepals, unequal in size, the lower one forming a hollow spur; five stamens inserted on lower

part of calyx; fruit a three-parted pod with parietal placenta leaves alternate and stipulate.

This family includes the many species and varieties of violets. These flowers were known through practically all historical time and are now grown very extensively to supply the flower markets of our cities. The cultivated pansy is a species of violet (*V. tricolor*) (Fig. 118).

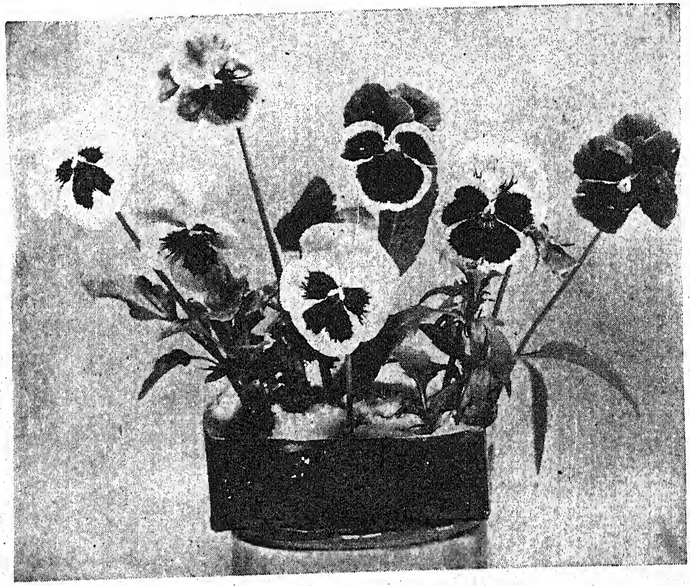


Fig. 118.—Pansies are so hardy as to stand much frost.

Commercial violets are grown from cuttings which are started in cool greenhouses. Common varieties of pansies are grown from seeds, but some of the more important commercial varieties are grown from layers or from cuttings made late in the season. If pansy beds are covered in the fall with a loose layer of grass or leaves, they will usually survive the winter and be more vigorous the second than the first year.

MALLOW FAMILY (MALVACEÆ)

The plants of this family are either herbs or shrubs. The flowers have five sepals united at the base, five petals, many stamens and a single- one-chambered ovary with many pistils. The mature fruit is a capsule.

Cotton.—In this family we find the cotton plants (*Gossypium herbaceum* L., *G. barbadense* L., *G. arboreum* L.) which are among the most valuable of the fibre or lint plants. The fibre is produced on the seeds within the capsule. The cotton plant was used long before Christ. It probably originated in India and spread throughout the tropical and subtropical parts of the world, although the early Spanish explorers claim to have found it growing in Mexico and Central America and that the natives were using it for making clothing. It is one of the most important crops of the southern states and is used for many purposes other than that of making clothing, such as gun-cotton and collodion. The oil is extracted from the seeds and used for culinary purposes and as a substitute for olive oil and the remaining solid part of the seed is used for stock feed. Cotton-seed meal is also used extensively as a fertilizer for the soil.

Accepting the idea that cotton is a native of both the old and the new world, it is evident that *G. herbaceum* is the old world form, *G. arboreum* (tree cotton) the African form and *G. barbadense* the American type. Many varieties of types are now recognized; one of the most popular of our American types is the "sea island" or "long staple cotton" which is a variety of *G. barbadense.*

The fruit of the **okra** or **gumbo** (*Hibiscus esculentus* L.) (Fig. 119) is extensively used in soups, stews and catsups, especially in the southern part of the United States. Its origin is unknown, but it probably originated in Africa or the American tropics.

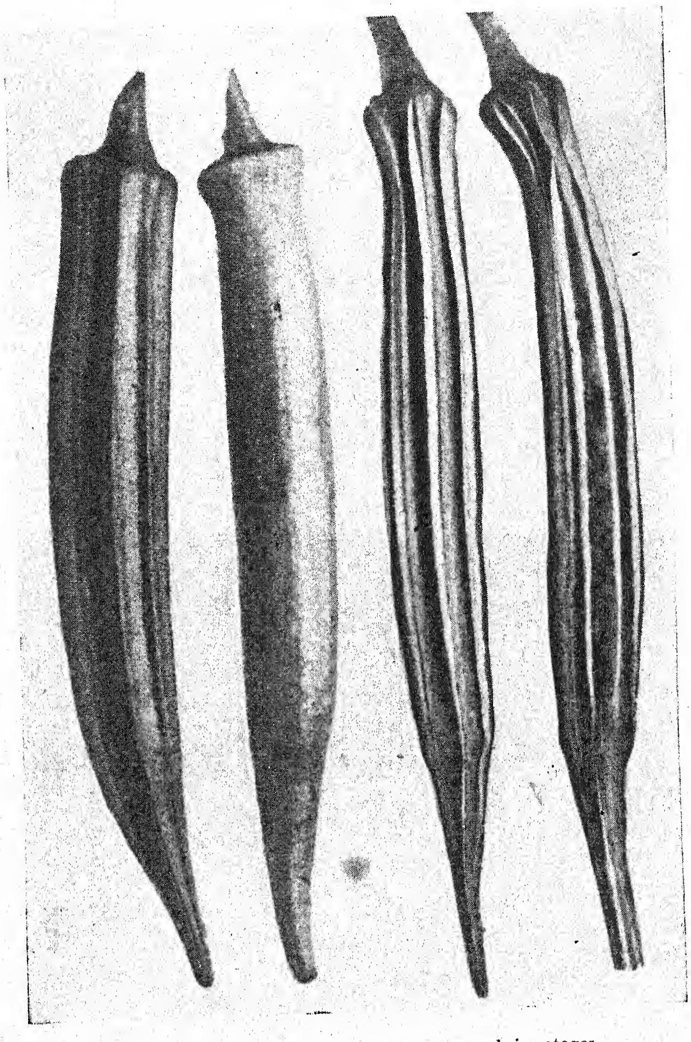


FIG. 119.—Pods of okra or gumbo in green and ripe stages.

The **Hollyhocks** (*Althæa rosea*) (Fig. 120), mallows and some other interesting ornamental plants belong to this family. Most of the members of this family are grown from seeds, but the hollyhocks and related forms persist from year to year. The cheese (*Malva rotundifolia*) and the Indian mallow or velvet weed (*Abutilon abutilon*) are common weeds.

STERCULIA FAMILY (STERCULIACEÆ)

The members of this family are trees or shrubs somewhat similar to the **Malvaceæ**, but the capsules are much larger and are fleshy. Here we find one of the very important plants which America gave to the world, the cocoa or **chocolate** plants—(*Theobroma cocoa*). It is tropical and was taken to Europe by the Spaniards about 1520, but it was more than a hundred years before its spread to England. It is now cultivated in other parts of the world, but the greater part of the supply comes from tropical America.

FLAX FAMILY (LINACEÆ)

Herbaceous, slightly woody plants with perfect, regular flowers, borne in terminal racemes or corymbs. Five sepals, occasionally four, hypogynous; stamens, same number as petals and alternate with them; styles three to five; ovary five to four chambers with two ovules in each chamber; fruit capsular.

Flax (*Linum usitatissimum* and *L. angustifolium*) is one of the most important fibre plants. It is supposed to have originated in some of the Mediterranean or Far East countries, but its use as a fibre plant began long before the Christian Era. This is a very important crop in some parts of the United States, especially in Minnesota and the Dakotas. It is grown primarily for the fibre which is used in the manufacture of linen and for the seed from which the linseed oil of commerce is extracted.

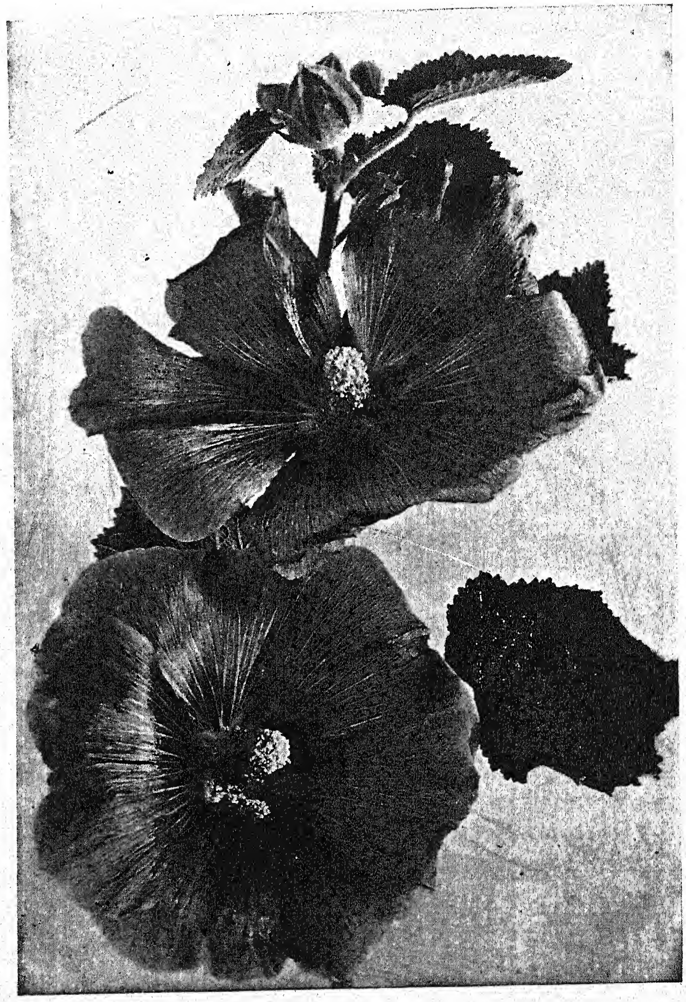


FIG. 120.—Hollyhock, representing the flower type of the mallow family.

The oil is used in the manufacture of paints, varnishes, patent leather, linoleum and other products. The cake and meal left after extracting the oil is used extensively for stock feed.

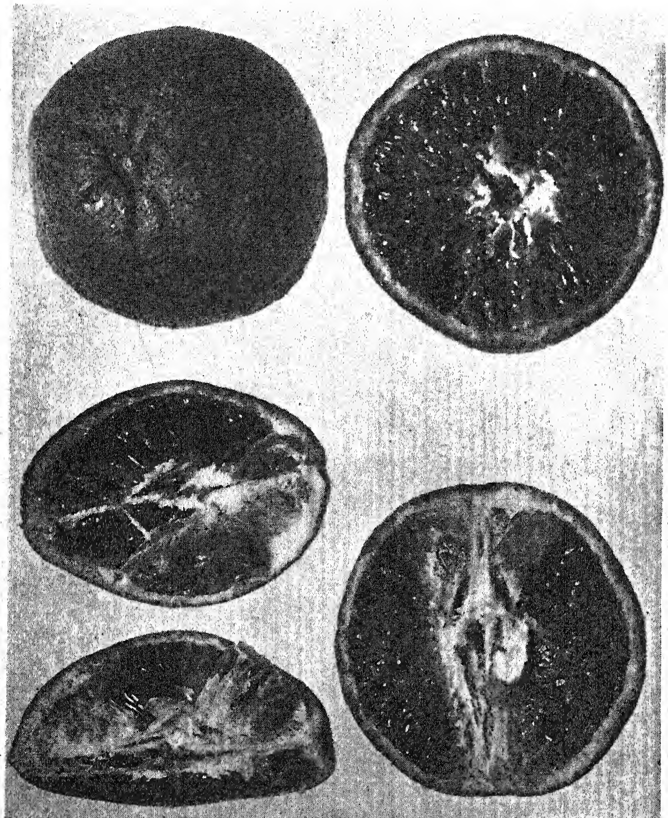


Fig. 121.—The sweet orange, often nearly seedless.

RUE FAMILY (RUTACEÆ)

Shrubs and small trees with perfect flowers. Five sepals; five to ten petals; many stamens; style one, ovary ripening into a many-chambered berry, capsule or samara.

The sweet orange (*Citrus aurantium*) (Fig. 121) is the best-known and most important fruit of this family. No one knows just where the orange came from or where it was first used by man, but it probably came from South China or India and was brought into Europe by the returning Crusaders or the Moorish invasion of Spain or possibly both. It was introduced into America by the early Spanish explorers.

The grapefruit (*C. decumana*), the **lemon** (*C. limonum*),

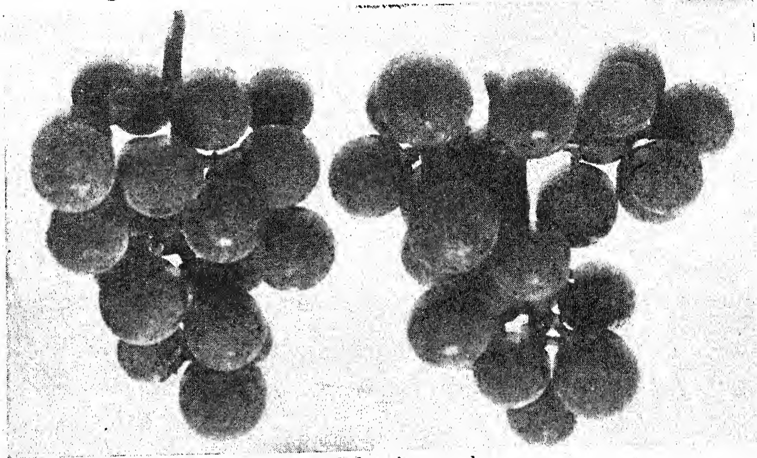


FIG. 122.—Modern improved grape.

the **lime** (*C. limetta*) and the **citron** (*C. medica*) are important members of this genus.

VINE FAMILY (VITACEÆ)

This family is made up of shrubs, usually climbing by means of tendrils; alternate, simple or compound leaves; flowers minute, greenish, perfect or imperfect; calyx entire or four to five toothed; petals four or five, separate or united and disappearing very soon after development; stamens four or five and opposite the petals; pistil one, consisting of two to six chambers; fruit usually a two-celled berry.

In this family we find the *grape* (Fig. 122), which is thought to be the oldest of the cultivated fruits. The very, very early historical records refer to grape-growing and wine. The most important grape of the old world is the *Vitis vinifera,* which is probably of Asiatic origin. In Europe, the grape is grown largely for wine, but it is also grown for raisins and other purposes. The effort to introduce the European grapes into the American colonies was a failure, owing to the fungous diseases and insects which destroyed them. But in time a number of

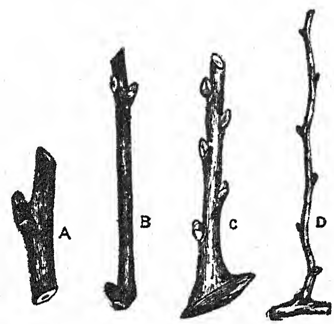


FIG. 123.—Grape-vine cuttings of four forms. A, one bud or single eye; B, simple cutting showing two buds; C, heel cutting with some of the wood of the larger stem; D, mallet cutting, with a piece cut out of the larger stem. (Productive Farming.)

good varieties were developed from the native American grapes. Among the most important are the Concord and Catawba types from *V. labrusca* and the Scuppernong from the *V. rotundifolia.* With the spread of civilization westward, the European grape has been introduced into southern California. In America the grapes are grown primarily for food instead of for the production of wine.

Propagation.—Grapes are usually propagated by means of cuttings, but can be grafted without great difficulty. Four common forms of grape cuttings are shown in Fig. 123. It is usual with our varieties east of the Mississippi to use simple cuttings with two or three buds, shown at B in the figure. Cut-

tings are made in early winter and stored in wet sawdust in a cool cellar. Here they form calluses over the wounds and elaborate the food stored in the tissues, and are ready to grow when set in the soil in the spring.

Some varieties are rooted in sharp sand under glass. Others are commonly planted in garden soils deep enough to allow only one bud to show. The soil should be tramped firmly. The planting is done after all danger of frost is over. They are set a few inches to one foot apart in rows, and the rows far enough apart to allow of clean cultivation. They should become well rooted and make some growth the first year in the garden or nursery. They may be then transplanted to the permanent vineyard. The distances apart in vineyards vary from six to twelve feet, depending upon varieties, method of trellising, and style of pruning to be used. The history of grape growing in America is extremely interesting and well worth reading. An excellent account is given in Bailey's "Evolution of Our Native Fruits."

This family also includes the Virginia creeper, Boston ivy, and some other ornamental vines.

SOAP BERRY OR MAPLE FAMILY (ACERACEÆ)

This family includes many shrubs and trees, with saccharine sap; leaves opposite, simple or palmately lobed, occasionally palmately or pinnately divided; flowers small, regular, usually polygamous or diœcious, occasionally apetalous; pistil one, two-chambered.

Maples.—This family contains the maples (Fig. 124) of the genus *Acer* which are very important as shade and ornamental trees. Among the most important of our native species are the silver maples (*A. saccharinum*), the red or scarlet maples (*A. rubrum*), the sugar or rock maples (*A. saccharinum*), the box elder (*A. negundo*) and others. The Norway maple (*A. platan-*

oides) is used extensively for shade and the Japanese species are used extensively for ornamental purposes.

A very excellent grade of sugar is made from the sap of the sugar maple and its manufacture forms a very important industry in some parts of the country, especially in the New England States and the northern states farther west. In the early history of the country, this was the most important and in many cases the only source of sugar for the early settlers.

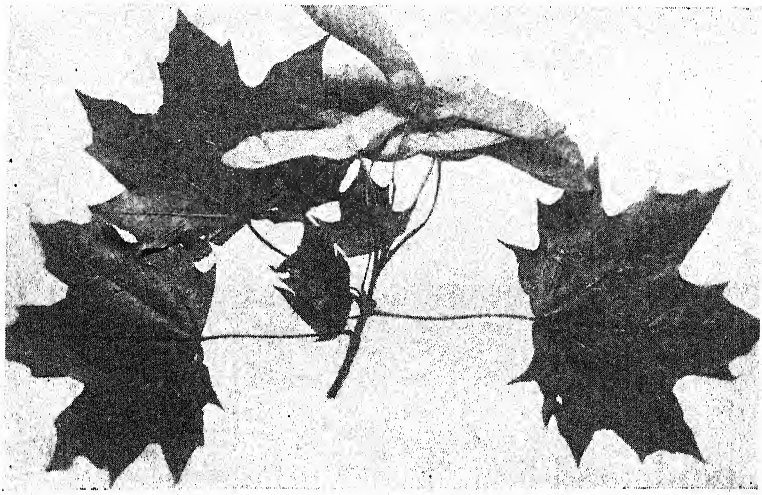


FIG. 124.—Maple.

Most species are grown from seeds sown one or two inches deep. The seeds of the early ripening species will not retain their vitality until the following spring and, therefore, should be sown as soon as possible after they fall from the tree. They can also be grown from layers and by grafting. Some fancy species and varieties are always propagated in this manner.

PEA FAMILY (LEGUMINOSEÆ)

This family includes herbs, shrubs, trees and vines; leaves alternate and usually odd-pinnately compound, with stipules;

flowers mostly irregular and often showy and papilionaceous (*i.e.,* butterfly-like); calyx four to five cleft; corolla usually of five petals which may be united (as in the case of the clover) or only partly united (as in the pea); stamens unusually 10 with all the stamens united (*monadelphous*) or nine united and one free, but forming a tube, enclosing the pistil; pistil one, with one chamber fruit usually a legume or pod.

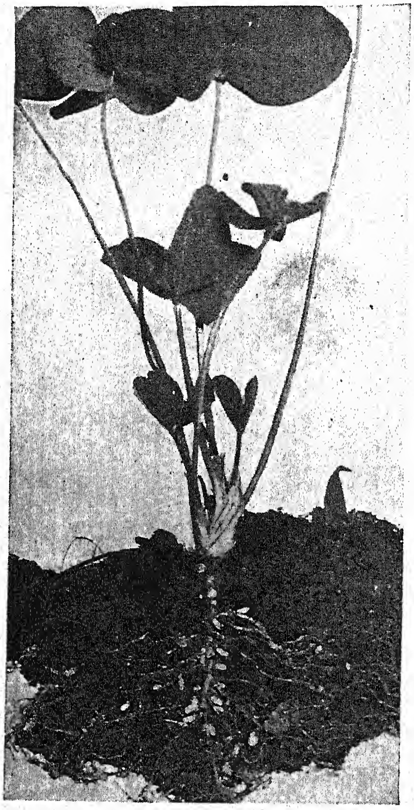


Fig. 125.—Red clover plant with nodules on the roots, containing bacteria which enable the plant to gather nitrogen from soil air. (Lights of the Farmer.)

This is one of the most important families, economically, to be found in the plant kingdom. It contains nearly four hundred and fifty genera and more than seven thousand species, many of which are important agricultural crops. They include cultivated crops used as food for man and beast; forest trees and ornamentals. The growing of leguminous crops is also recognized as one of the best methods of improving the soil.

Legumes Gather Nitrogen.—The use of legumes in the improvement of soils depends upon the partnership (or symbiosis) existing between these plants and certain nitrogen-gathering bacteria which make their homes on the roots (Fig.

125). The nodules seen on the roots are the homes of the bacteria. When the bacteria are present on the roots the plants are enabled to gather nitrogen from the air. This power is not found in other families of plants.

The relationship existing between the plants of the legume family and the bacteria on the roots is a kind of partnership (or symbiosis). The clover plant, for example, furnishes homes for the bacteria and supplies them with nourishment.

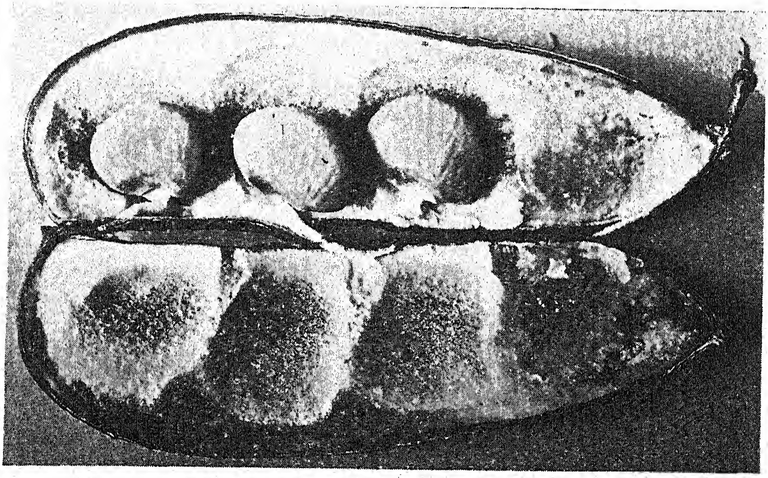


FIG. 126.—Pod and seeds of lima bean.

In return for these benefits, the bacteria enable the clover plant to gather nitrogen from the air and use it in its own growth.

Different kinds of bacteria are found to suit the different legumes. The red clover bacteria do not thrive on alfalfa or on beans. There are some forms of bacteria that are adapted to several legumes. For example, those on alfalfa are also found on sweet clover and on bur clover.

Legumes aid other crops grown in the same soil after them. If clover or cowpeas, for example, are plowed under,

the nitrogen which they have gathered and stored in their leaves, stems and roots is added to the soil. This may soon be changed to forms which corn, potatoes, or other crops may use while growing in that soil.

Beans.—The term "bean" is applied to many plants of this family; the broad bean (*Vicia faba*) is of Asiatic origin

FIG. 127.—Alfalfa and clover.

and is extensively grown in Europe for the feeding of live stock; the kidney bean (*Phaseolus vulgaris*) probably originated in tropical America and is represented by many species and varieties of garden and field beans which are so extensively grown throughout the world; the Lima bean (*P. lunatus*) (Fig. 126) is a native of South America, the soy or soja bean (*Glycine hispida*) is of Asiatic origin and is grown extensively for stock feed; the so-called cowpea or bean (*Vigna simensis*) is

also grown extensively for the same purpose; the scarlet runner (*P. multiflorus*) is an interesting ornamental.

Peas.—The common garden pea (*Pisum sativum*) is well known as one of our most valuable garden crops and is frequently grown very extensively for canning.

Clovers.—The genus *Trifolium* includes about three hundred species of clovers (Fig. 127), many of which are numbered among our most important agricultural crops.

The most important clovers are the red clover (*Trifolium pratense* L.) the mammoth clover (*T. medium*), the white clover (*T. repens*), the alsike or Swedish clover (*T. hybridum*) and the crimson or scarlet clover (*T. incarnatum*).

The term clover is also often applied to other genera, such as the alfalfa (*Medicago sativa*) (Fig. 127), the common yellow clover or trefoil (*M. lupulina*), the bur clover (*M. denticulata*), the sweet clovers (*Melilotus alba, M. officinalis*), the bush or Japan clover (*Lespedeza striata*).

Peanut.—This family also includes the peanut (*Arachis hypogœa*) (Fig. 128), licorice plant (*Glycyrrhiza glabra*), the indigo plant (*Indigofera tinctoria*) and many other plants which are valuable as forest trees, field crops, drug plants, etc.

The peanut has a peculiar habit of sending down a long flower stem to thrust the young seed into the mellow soil near the roots. This occurs just after pollination. The pod develops and ripens under ground. The crop is grown for forage as well as for the peanuts themselves. There are chiefly two types of peanuts commercially grown for human use: the large Virginia type and the small Spanish type. The latter is commonly used in candies, for making peanut butter, and for extracting oil.

The garden and field crops are very generally grown from the seeds, and the production of the commercial supply is a very important industry. Great care should be exercised to guarantee seeds true to name and free from weed seeds.

ROSE FAMILY (ROSACEÆ)

This is the most important fruit producing family in the plant kingdom. The flowers are perfect and regular. There

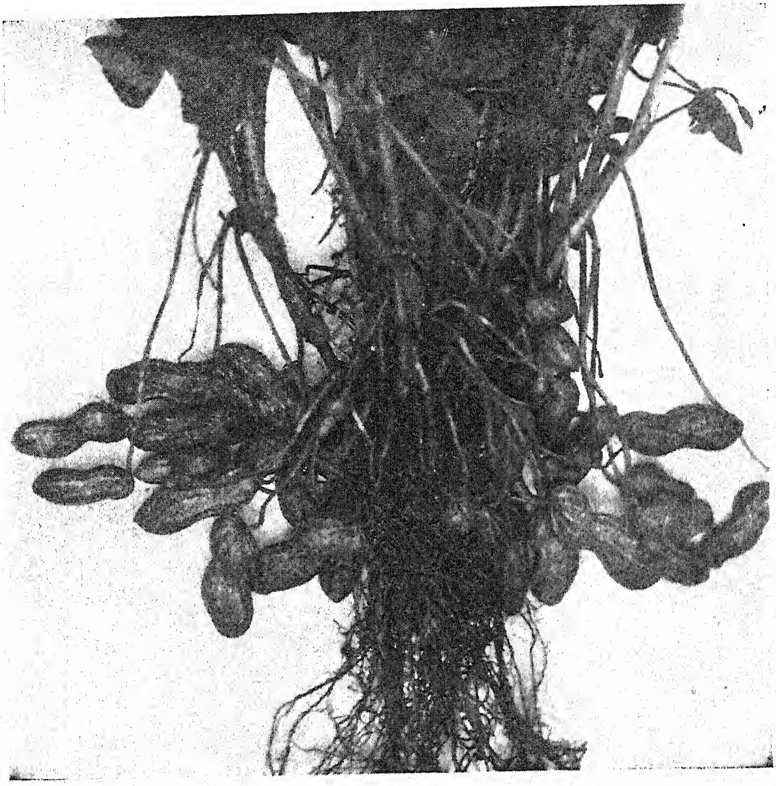


FIG. 128.—Peanut plant with the elongated stems sending seeds into the soil shown at right and left.

are usually five sepals, five petals and many stamens, but the character of the ovary is extremely variable in the different genera. The wild rose may be taken as a type; it possesses the above characters and has an inferior ovary.

The apple (*Pyrus malus*) (Fig. 129) shows the same general characters, but the ovary becomes fleshy and shows a division into five well-developed parts. It probably originated in southwestern Asia and adjacent Europe and was used by the human race in prehistoric times.

The pear (*P. communis*) and the **quince** (*P. cydonia*) are very similar in character to the apple.

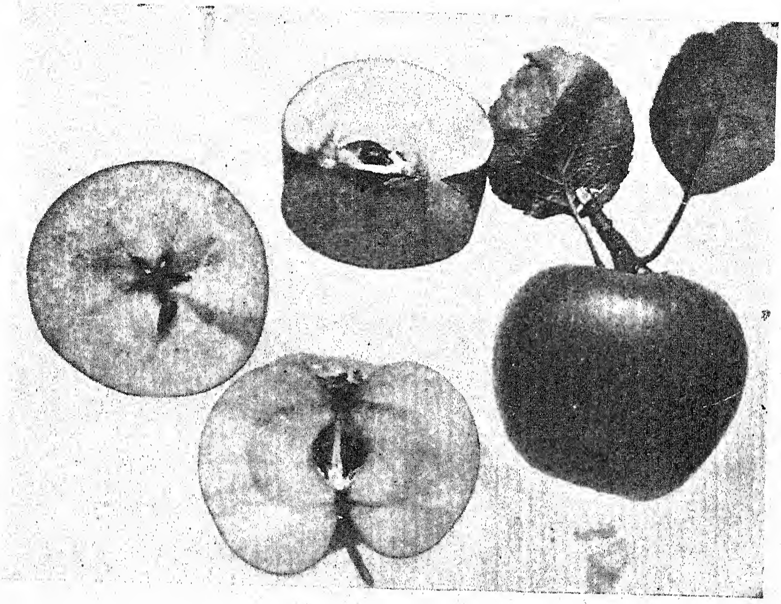


FIG. 129.—Apple, with section showing structure of seed cases.

The peach (*Prunus persica*) (Fig. 130) shows the same general character of sepals, petals and stamens as the preceding, but the ovary is superior and develops into a fleshy fruit with a single hard-shelled seed. It is undoubtedly of Asiatic origin, but was carried into Europe by the Greeks and Romans at a very early date. It was introduced into Great Britain during the sixteenth century and thence into America about 1680. It

reaches its greatest perfection in China and in the United States. The **almonds** (*P. communis* and *P. nana*) are closely related to the peach; and the nectarines are smooth-skinned varieties of the peach.

Plums also belong to the genus *Prunus* (*P. domestica*—Damson plum) and are also said to be of Asiatic origin, although some botanists claim that they are indigenous to Europe. The prunes of commerce are varieties of plums which are espe-

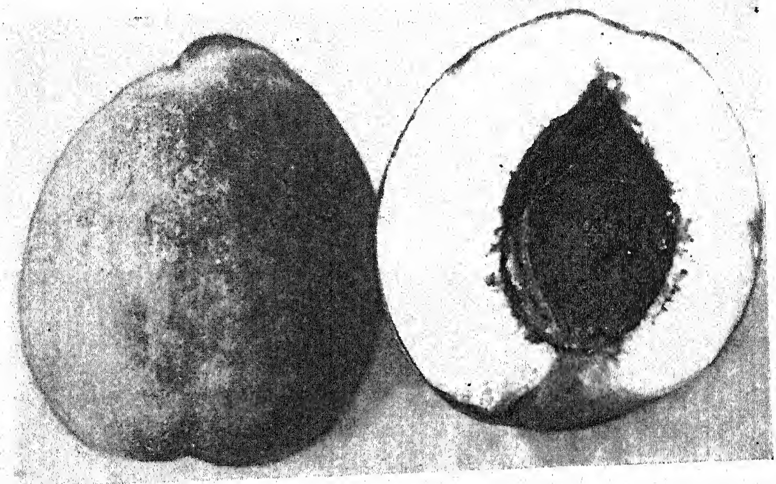


FIG. 130.—Peach, an example of the stone fruits. The plum and cherry are other examples.

cially well adapted to drying. There are also several species of American plums.

Cherries also belong to the genus *Prunus* and are well known in both Europe and America.

Raspberries, blackberries (Fig. 131) **and dewberries** belong to the genus *Rubus* of the family Rosaceæ. In most cases there are five petals and five sepals and many stamens as in the preceding genera, but they differ from the preceding in having a number of ovaries which ripen into the well-known aggregate fruit.

In the blackberries and dewberries, the receptacle forms a part of the fruit, but in the raspberries the ovaries are separated from the receptacle.

Strawberries (Fig. 132) belong to the genus *Fragaria* and have flowers very similar to the members of the genus *Rubus,* but

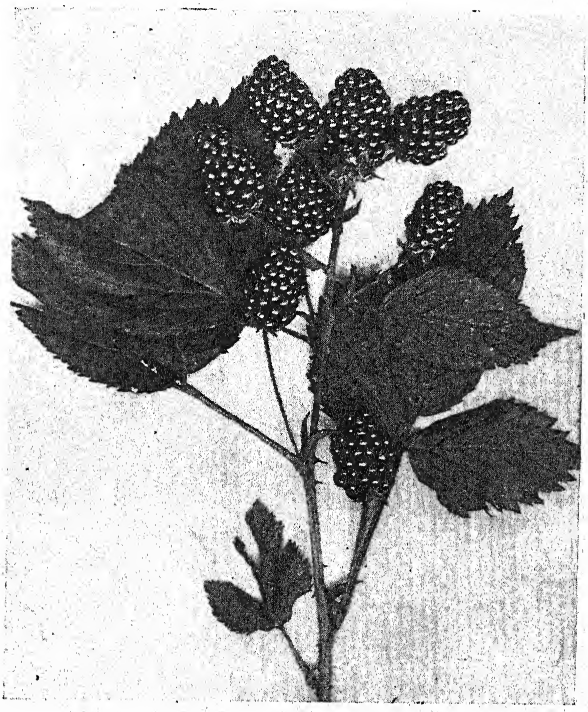


FIG. 131.—Blackberry, a form of aggregate fruit.

fruit consists primarily of a large fleshy receptacle carrying numerous naked akenes on its surface.

Pollination of Strawberries.—The flowers of some varieties of strawberries have very little or no pollen. The two types of blossoms, with and without stamens, are shown in Fig. 133. Growers are unable to obtain fruit from the imperfect va-

rieties (not having pollen) unless those with perfect flowers are grown near them. The two types may be planted together, with at least one row of a perfect-flowered sort for three or four rows of the imperfect ones, and these must be such as blossom at the same season.

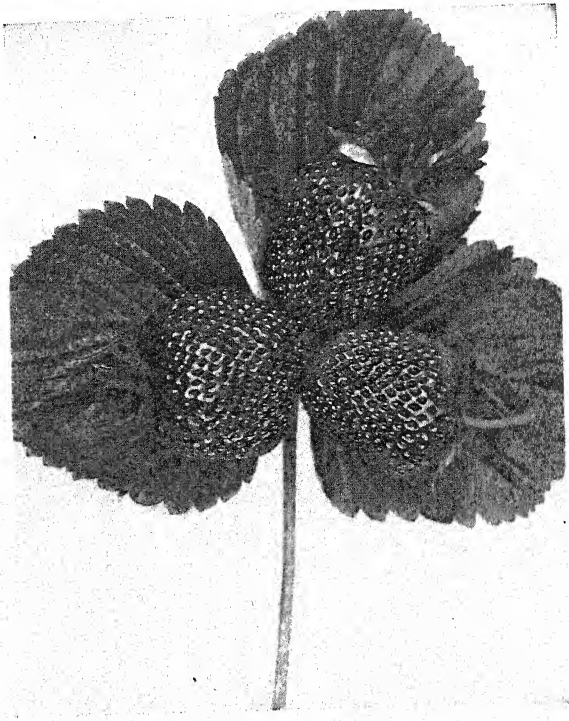


FIG. 132.—Strawberry.

The perfect-flowered varieties will produce fruit when planted alone. They are more popular than the others. Two varieties with imperfect flowers are Warfield and Haverland. Crescent and Glen Mary bear very little pollen. Over fifty perfect-flowered varieties are known. Some of these are Dunlap, Aroma, Gandy and Excelsior.

As the strawberry propagates itself by means of runners which take root at the nodes, the varieties are easily kept pure. The crossing of the pollen does not affect the character of the fruit or the purity of the plants grown from the runners.

Poorly developed fruits, called "nubbins," are often the result of poor pollination. This may be due to one of several causes: (a) frost, (b) hail, (c) rain, (d) spattering of soil on the pistils, (e) insufficient pollen on varieties blooming late in the season. Mulches of straw or other litter will prevent injury from spattering soil during heavy storms. Growing several varieties together will aid in supplying enough vigorous pollen and cause better development of the fruit.

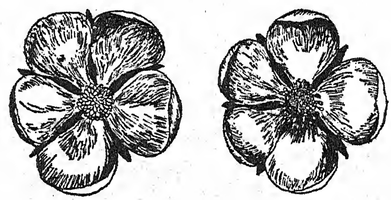


FIG. 133. — Flowers of strawberries. Pistillate or imperfect at left. Perfect at right. (Productive Farming.)

Propagation. — Apples, pears, and quinces are pomaceous fruits and propagated by growing stocks from seeds, then budding and grafting with the desired varieties. The seeds are obtained from the pomace of the cider mills. For many years it was very generally believed that seeds and stocks from France were better than the domestic supply, but in recent years the sentiment has been changing and a very important stock-growing industry has developed in Kansas, Nebraska, Iowa and other states.

Blackberries, dewberries and raspberries are usually grown from suckers and root cuttings. New varieties are grown from seed.

Budding of Peaches and Plums.—The steps in the method of shield-budding are shown in Fig. 134. The seeds are sprouted in early spring after being mechanically cracked, or broken by freezing in moist soil. Scions are cut from the current season's growth in August and September, and the buds from these are

inserted under the bark of the young seedlings right away. These buds remain dormant until spring. When growth begins the seedling top is pruned away, leaving only the shoot of the good variety.

For June budding, dormant buds are gathered in late fall and held until June in wet sawdust in a cold cellar or in other cold storage. The budding is done in June on seedlings started in very early spring.

Root Grafting of Apples and Pears.—When trees are to be

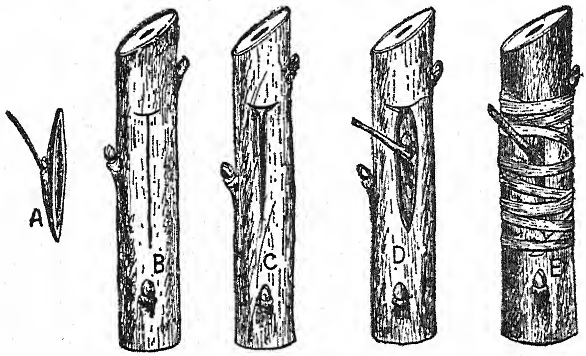


FIG. 134.—Steps in budding the stems of seedlings with buds of good varieties. A, the shield-shaped bud and parts cut from any good variety. B, a T-shaped cut made in the bark of the seedling stem. C, the same with bark opened. D, the good bud set in place under bark. E, the wound well wrapped and tied with raffia or waxed cotton. (Productive Farming.)

propagated by root grafts (Fig. 135), the tongue-grafting is usually done in the winter. The seedlings of one season's growth are dug in the fall after the leaves are off. They are stored in small bundles in boxes of wet sawdust in a cold cellar. The scions from the desired varieties are gathered about the same time. They are labeled and stored in like manner. The spare hours of winter are used for the work, which should be done in a cool room or cellar. The materials and new grafts must be kept moist and cool during the process. The grafts are then stored in wet sand or sawdust in a cool cellar till dan-

ger of severe frost is over in the spring. They are then set in rows in good garden soil. They are planted deep enough to leave only one or two buds above ground. Here they are grown for a year or more before being transplanted to the orchard.

The peach, plum and cherry are drupaceous fruits and are usually propagated by growing stock from seeds and then budding or occasionally grafting. Plums are sometimes grown from suckers.

SAXIFRAGE FAMILY (SAXIFRAGACEÆ)

Herbs or shrubs with perfect, regular (occasionally irregular) flowers. Calyx more or less united with the ovary, four to five petals attached to calyx, stamens same number as the petals and alternate with them or two to ten times as many. Ovary more or less inferior. Fruit a two-chambered capsule or true berry. Leaves alternate or opposite or whorled.

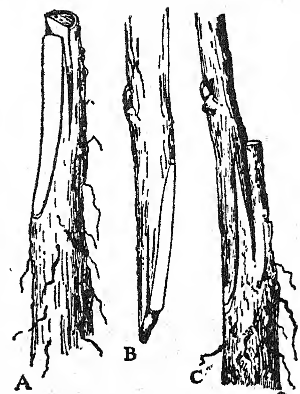


Fig. 135.—Steps in making the tongue-graft used in root grafting apples, pears, etc. A and B, root and scion with tongue cut in each. C, the two shoved together and ready to be tied with waxed cotton. (Productive Farming.)

Currant and Gooseberry.—The common red currant (*Ribes rubrum*), the black currants (*R. floridum* and *R. nigrum*), the gooseberries (*R. grossularia* and *R. cynosbate*), the American gooseberry (*R. hirtellum*) and many species and varieties of currants and gooseberries (Fig. 136) are valuable fruits. They are extensively grown as garden fruits, but the historical records are very imperfect and uncertain.

Gooseberries and currants are usually obtained from hardwood cuttings, but new varieties are grown from seed.

GOURD FAMILY (CUCURBITACEÆ)

This very important family has monœcious or diœcious, occasionally perfect, usually solitary white or yellow flowers (Fig.

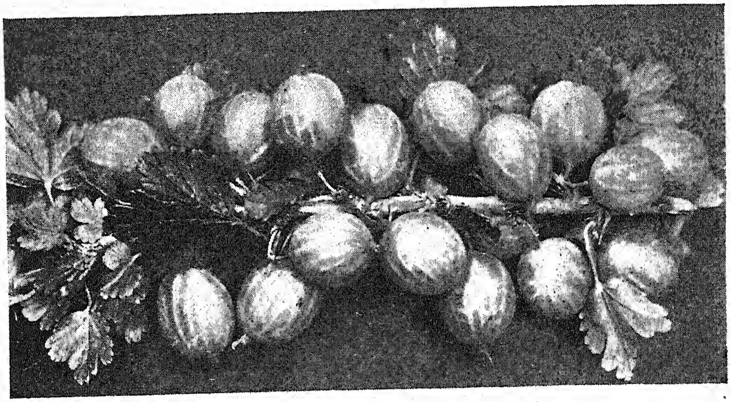


FIG. 136.—Gooseberry.

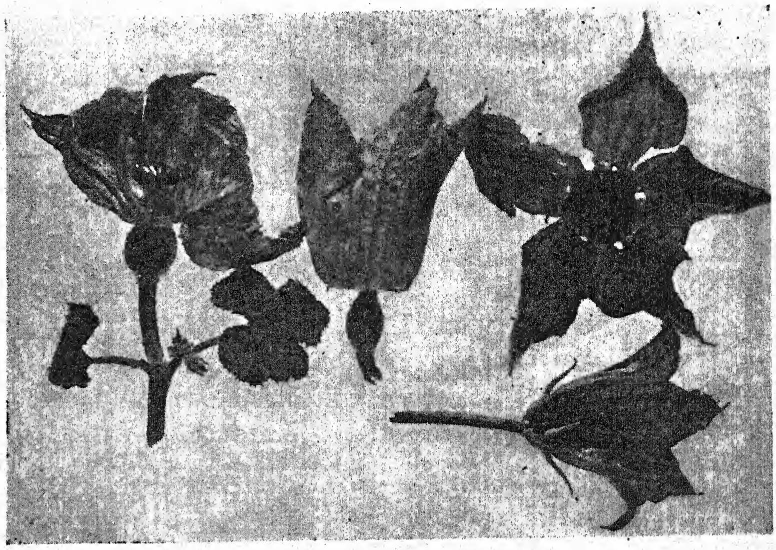


FIG. 137.—Cucurbit blossom.

137.) Calyx five-cleft and bell-shaped; corolla five-cleft and bell- or wheel-shaped; stamens five, ovary inferior and one to many chambered, developing into a many-seeded true berry fruit. In many species the fruit is large and fleshy and edible. Among the most important are:

The cucumber (*Cucumis sativus*), which is of Asiatic origin and was cultivated about three thousand years before

FIG. 138.—Ribbed type of cantaloupe.

the Christian Era. **The muskmelon or cantaloupe** (*C. melo*) (Fig. 138), is indigenous to Asia and possibly to Africa. It was cultivated by the ancient Egyptians and was known to the early Greeks and Romans. **The watermelon** (*Citrullus vulgaris*) is a native of the torrid regions of Africa, but was cultivated long before the Christian Era. It is now widely distributed throughout the tropical and temperate zones.

The pumpkin, gourd, and squash—(*Cucurbita melopepo*) flat squash, (*C. verrucosa*) warty or long-necked squash, (*C.*

maxima) winter or gourd squash, (*C. pepo*) pumpkin—are well-known products of both tropical and temperate climates. The pumpkin is supposed to be of American origin.

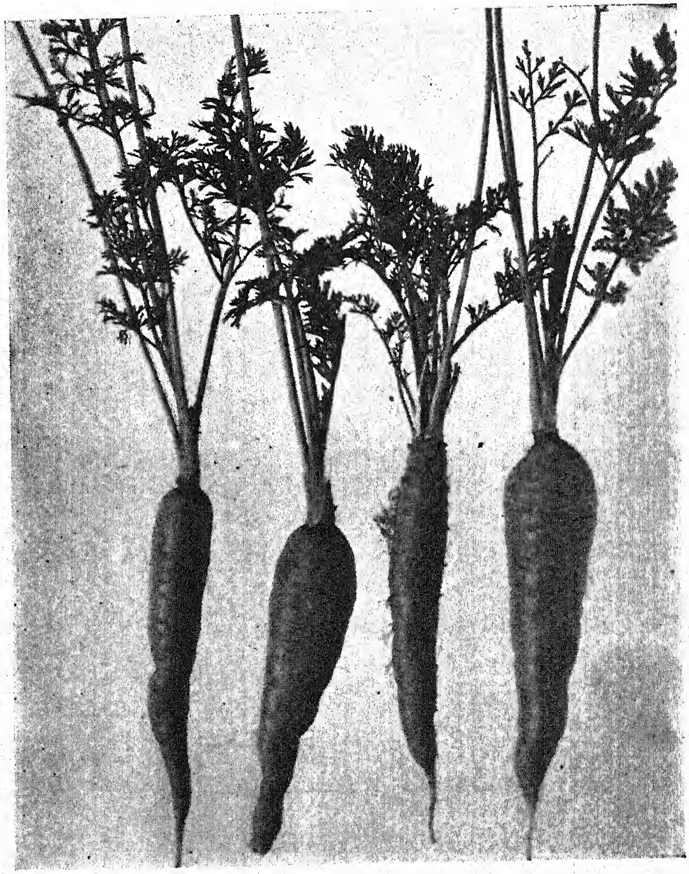


Fig. 139.—The long form of carrot.

The members of this family are very generally grown from seed and are widely distributed throughout the temperate and tropical climates. The growing of cucumbers under glass has

developed into an important industry near many of our large cities. The weed members of this family are of no very great importance.

PARSLEY FAMILY (UMBELLIFERÆ)

The family is characterized by five-parted calyx and corolla; two-chambered inferior ovary and umbel inflorescence. Among the most important members are: **The celery** (*Apium graveolens*), which is well known. It was used as food by the ancient Egyptians, Greeks and Romans and also as a medicine by the Egyptians. **The parsnip** (*Pastinaca sativa*) originated in Europe but is now widely cultivated as a food for man and live stock. **The carrot** (*Daucus carota*) (Fig. 139) is a vegetable whose history is not known.

This family also includes the anise (*Pimpinella anisum*); asafœtida (*Ferula narthex*); coriander (*Coriandrum sativum*); parsley (*Carum petroselinum*); caraway (*Carum carui*); and many other more or less well-known plants, some of which are useful while others are pests.

The members of this family are grown from the seed. Celery, parsnips and carrots may be kept in storage for considerable time. This family also includes a number of weeds which can be kept in control by the use of cultivated crops and also by the use of cowpeas, soy beans or similar smother crops.

MADDER FAMILY (RUBIACEÆ)

Coffee and Quinine.—This family includes the coffee (*Coffea arabica* and *C. liberica*), the quinine plant (*Cinchona officinalis*) and other plants with interesting histories. (Read the history of these plants in an encyclopedia.)

SUNFLOWER OR COMPOSITE FAMILY (COMPOSITÆ)

This is one of the largest families of the flowering plants. It is characterized by numerous small flowers growing in a close head. These flowers are either polygamous or monœcious. The ovary is inferior and the calyx tube is attached to it; the corolla is five cleft, either tubular or strap-shaped; stamens five, attached to corolla; anthers united into a tube surrounding the two-cleft style. In most plants the central or disk flowers are

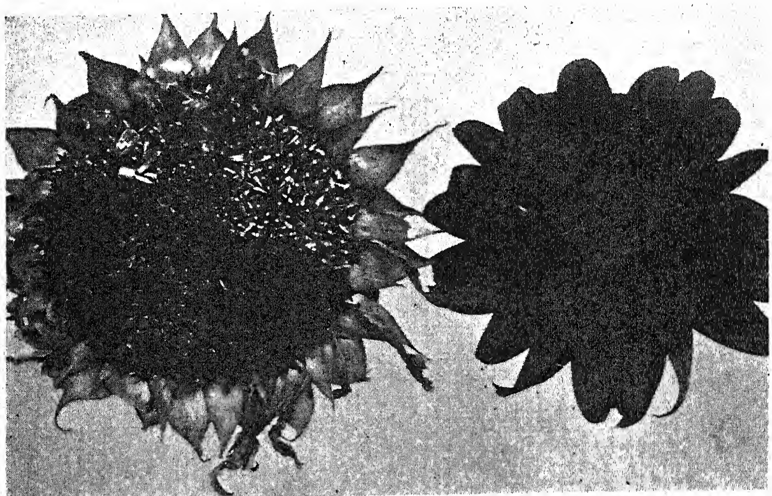


FIG. 140.—Sunflower, showing the composite flower head.

tubular and the marginal flower strap-shaped, but in some plants all of the flowers are of the same kind.

This family includes some few plants used for food, such as the Jerusalem artichoke (*Helianthus tuberosus* L.), lettuce (*Lactuca sativa*), some few others that are used in medicines, and a large number that are used for ornamental purposes, such as the sunflower (*Helianthus annuus*) (Fig. 140), the daisy and chrysanthemum (*Chrysanthemum carineum*), goldenrods (*Solidagos*), asters, dahlias and others.

This family also includes the dandelion (*Taraxacum officinale*), iron weed (*Vernonia*), fleabane and meadow white top (*Erigeron*), thistle (*Carduus*), and many others that are troublesome as weeds.

HEATH FAMILY (VACCINIACEÆ)

The flowers of this very interesting family are four to five parted; calyx attached to an inferior ovary, the petals united;

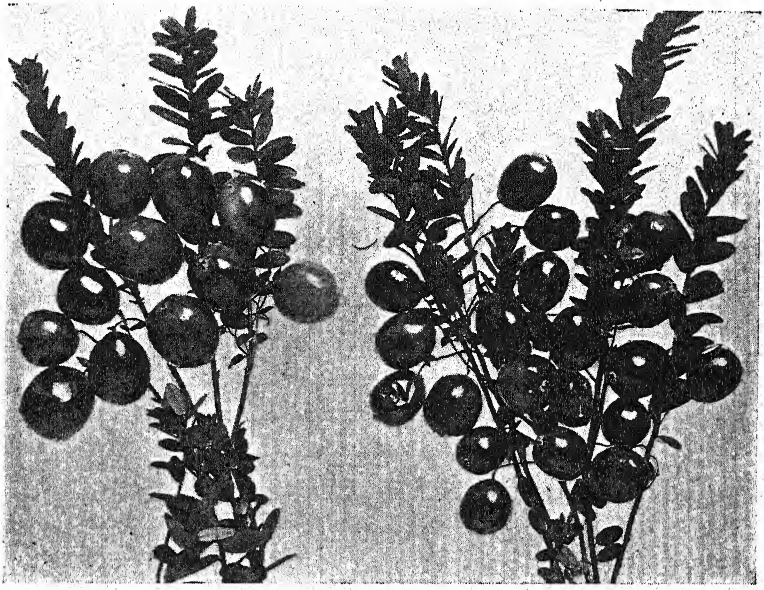


FIG. 141.—Cranberries.

stamens eight to ten; ovary of several chambers and developing into a true berry.

Blueberry, Huckleberry and Cranberry.—The most important plants of this family are the blueberries and huckleberries (*Gaylussacia*) and the cranberries (*Oxycoccus*) (Fig. 141), both of which are indigenous to America.

Cranberry-growing is a highly specialized industry which is

restricted to very limited parts of the country. The conditions for success in this line of farming are to be found in very few parts of the country. Old peat bogs with an ample supply of water are essential.

CONVOLVULUS FAMILY (CONVOLVULACEÆ)

The flowers of this family are perfect and terminal; calyx five-cleft and persistent; corolla, funnel-shaped and five-cleft; stamens five and attached to the corolla. The family contains a large number of ornamental plants of which the morning glory is typical. Many of these plants are so common as to be weed pests.

Sweet Potato.—The most important economic member of this family is the sweet potato (*Ipomœa batatas*). Some authorities claim that this plant is Asiatic, while others claim that it is American. It may possibly be indigenous to both continents. It reaches its greatest development in the tropical countries, where it makes a very luxuriant growth and blooms freely, but it is extensively cultivated in the sandy districts of the temperate zones. Certain varieties are cultivated under the name of yams, but the true yam belongs to the family *Dioscoreaceæ*.

Propagation.—In the temperate zone, sweet potato plants are grown from roots which are laid in hot-beds, cold-frames or forcing houses, dependent upon the climatic conditions. The plants are then transferred to the field and are most productive in sandy soil. In tropical countries, the crops are usually grown from cuttings set directly in the field. This family includes a number of very troublesome weeds, which are difficult to eradicate except by the use of cowpeas, soy beans or similar smother crops.

This family also includes the dodder or love vine, which we find growing parasitically on many of our flowering plants.

The seeds germinate in the soil, but the vine very soon attaches itself to another plant and loses its connection with the soil, thus becoming strictly parasitic. Some of the dodders are very troublesome weeds.

NIGHTSHADE FAMILY (SOLANACEÆ)

This is one of the most important families in the plant kingdom. The calyx is five-cleft (occasionally four or six) and

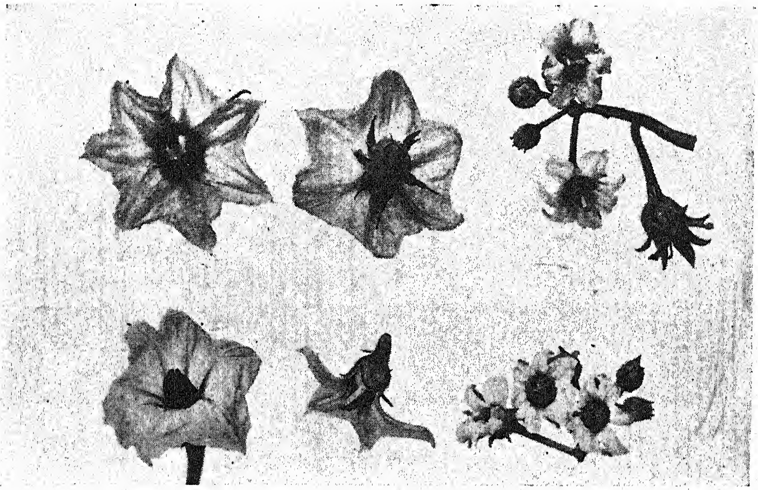


FIG. 142.—Blossom of egg-plant. Note its similarity to the Irish potato blossom.

persistent; corolla five-cleft (sometimes so deeply that the petals appear to be distinct); stamens five and attached to the corolla; ovary two- to five-chambered and with many ovules. (Fig. 142.) Fruit varying from a dry pod to a true fleshy berry. The most important members of this family are:

The potato (*Solanum tuberosum*) is indigenous to Chile, Peru and Equador, where it was found growing by the early Spanish explorers. It is now widely distributed throughout the world and is one of our most important food products. The wild potatoes produce small tubers and many seeds, but careful

selection has given us many varieties with large tubers and few or no seeds.

The tomato (*Lycopersicum esculentum*) (Fig. 143) is a native of Central and South America and is said to have been cultivated by the ancient inhabitants of Mexico. Its uses are well known.

The pepper (*Capsicum annuum*) (Fig. 144) (red pepper.

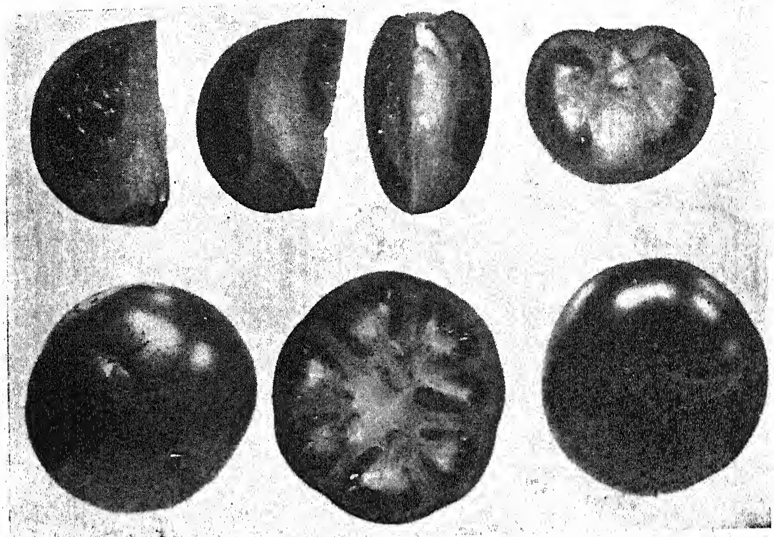


Fig. 143.—Tomatoes.

C. *fastigiatum* and *C. fructescens*, Cayenne pepper, and *C. grossum*, bell pepper) is also indigenous to tropical and subtropical America. The uses are well known.

Tobacco (*Nicotiana tabacum*) is another well-known American plant which is now cultivated in many parts of the world.

This family also includes the deadly nightshade (*Atropa belladonna*) from which certain important drugs are obtained, the common black nightshade (*Solanum nigrum*), and many other interesting plants.

Propagation.—It is well known that the potato is grown from the tubers, but the other cultivated members of this family are very generally grown from seeds. The seedlings are read-

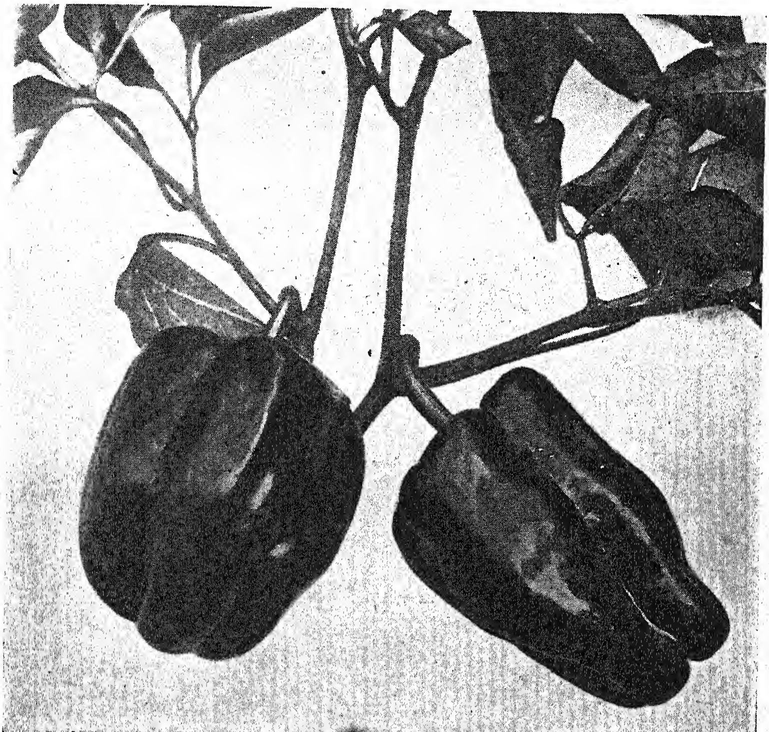


FIG. 144.—The sweet pepper.

ily transplanted. This family also contains a few troublesome weeds which can usually be controlled by smother crops.

GOOSEFOOT FAMILY (CHENOPODIACEÆ)

The members of this family are very widely distributed. They are mostly herbaceous with alternate leaves; flowers small, greenish, in spikes or beads, usually regular; no corolla; calyx

three to five lobed (rarely one or no sepals); stamens as many as lobes of calyx or fewer; pistil one with one chamber; fruit one-seeded in a loose bladdery capsule or utricle.

Beets, Spinach and Swiss Chard.—This family includes the common beet (*Beta vulgaris*) (Fig. 145), which is indigenous to both Europe and Asia and was used for five hundred years or more before the Christian Era. Some varieties are extensively used as a table vegetable, others for stock feed and still others for the manufacture of sugar. The spinach is an Asiatic plant which has been cultivated and used from unknown time. The Swiss chard, which is so extensively used as a salad, is a variety of the common beet.

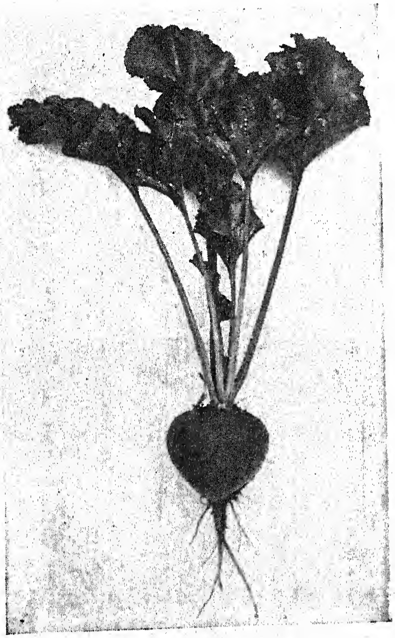


Fig. 145.—The table beet.

BUCKWHEAT FAMILY
(POLYGONACEÆ)

Buckwheat.—This family includes the buckwheat (*Fagopyrum esculentum*) (Fig. 146), an Asiatic plant which is well known. It was at one time known as beech wheat, owing to the resemblance of the seed to that of the beech, but this was gradually modified to "buckwheat."

Rhubarb.—This family also includes the well-known vegetable, rhubarb or pie-plant (*Rheum rhaponticum*), which is of East European or West Asiatic origin.

Buckwheat is grown from seed. Rhubarb may be grown

from the seed, but will not come true to type and requires three years to come to maturity. It is much better to secure new plants by dividing the crowns. This family includes many important weeds; among the most troublesome is the sorrel, which grows in great abundance in sour (acid) soil. It can

Fig. 146.—Buckwheat.

be eradicated by heavy applications of lime and the use of legume crops. The docks are also members of this family.

NETTLE FAMILY (URTICACEÆ)

This family contains herbs, shrubs and trees and includes some very important plants. Flowers monœcious, diœcious or rarely with perfect flowers; calyx regular; stamens as many as the tubes of the calyx or fewer and opposite them; pistil one with two cells.

The mulberry (*Morus rubra,* American red mulberry, and *M. alba,* Asiatic white mulberry) is well known. The flowers

are unisexual and the plants are usually monœcious. Both male and female flowers are borne on short spikes and have a four-parted perianth or calyx. The white mulberry was introduced into Europe about the middle of the fifteenth century, into Mexico by Cortez in 1522 and into Virginia by James I

FIG. 147.—Fig.

in 1619. It is extensively grown in China for the feeding of the silk worm. The American mulberry produces a very good fruit and the wood is very durable and serviceable for many purposes.

The elms (*Ulmus Americana*, American or white elm; *U. fulva*, slippery or red elm; *U. racemosa*, corky elm) are among our most valuable shade and ornamental trees.

The common hop (*Humulus lupulus*) is well known. It is used in making yeast, beer and medicine.

Fig and Rubber.—The genus *Ficus* includes the common fig (*Ficus carica*) (Fig. 147), the India rubber tree (*F. elastica*) and the banyan tree (*F. bengalensis*).

The hemp (*Cannabis sativa*) also belongs to this family.

Propagation.—The mulberry is usually grown from root cuttings, or from layerings, or by budding. New varieties are obtained from seeds. The elms are usually grown from seeds which mature very early in the spring and are sown at once, but may also be grown by layering or by grafting. Hops may be grown from seeds, from divisions or from hard wood cuttings. Hemp is grown from seed and is one of the very important fibre plants.

WALNUT FAMILY (JUGLANDACEÆ)

This very important family contains two valuable groups of trees, the walnut and the hickory. The flowers are monœcious. The staminate flowers are usually borne in catkins and each consists of a six-lobed (occasionally two- or three-lobed) perianth and from six to forty stamens. The pistillate flowers are terminal and may be solitary, few or clustered; the calyx tube is four-toothed and styles two in number. The fruit is a drupaceous nut.

Walnuts.—The American black walnut (*Juglans nigra*) is well known both for the nuts and for the high quality of the wood. The American butter-nut (*J. cinerea*) produces an excellent nut, but the wood is not so valuable as that of the black walnut. The so-called English walnut (*J. regia*), which is now extensively cultivated in many parts of the world, is of Asiatic origin. It is of great value both for nuts and lumber.

Hickories.—The various species of hickory (*Hicoria ovata,*

shell bark, and *H. olivæformis, H. pecan,* the pecan of commerce) are well known for their nuts and useful woods.

Propagation.—The members of this family can be grown from seeds or by grafting. The fact that seedlings are subject to more or less variation makes it necessary to perpetuate desirable varieties by grafting, which must be done with considerable care in order to be successful.

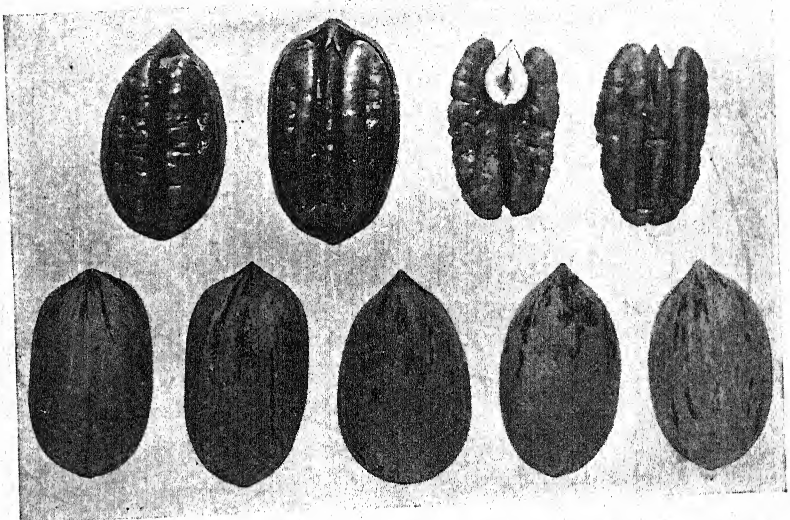


FIG. 148.—Pecan nuts, showing one of the many forms grown for market. (U. S. D. A.)

OAK FAMILY (CUPULIFERÆ)

This family is similar to the preceding. The flowers are monœcious. The staminate flowers in catkins, calyx five-parted (occasionally five to twelve), stamens two to twenty. The pistillate flowers terminal, six-parted, and attached to the two- to seven-chambered ovary. Fruit a one-seeded nut. This family includes the oaks, chestnut, hazelnuts, beech, and others.

There are many species of oaks (*Quercus*) which are among

the most important of our forest trees. The hazelnuts (*Corylus*) and the chestnuts (*Castanea*) are highly prized for their edible nuts.

Feed for Swine.—The nuts of the trees of this family and the preceding one are abundantly used in feeding swine. The animals are allowed to gather the acorns and nuts (called mast) from the ground under the trees, during the fall and winter days when there is no snow on the ground. The flesh produced from mast is often of good quality, and the economy of its production is readily understood. Beechnuts alone produce a soft flesh, and some corn or other grain is fed for a few weeks before slaughtering.

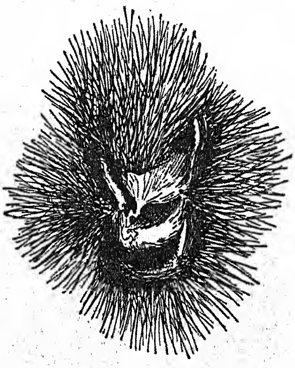


FIG. 149.—Bur of native chestnut showing two seeds within. ("Productive Plant Husbandry.")

WILLOW FAMILY (SALICACEÆ)

In this family, both the staminate and pistillate flowers are borne in catkins. It includes the willows (*Salix*), the poplars, and the cottonwoods (*Populus*).

All members of this family grow readily from cuttings and can be grown from grafts. The poplars and cottonwoods are frequently grown from seed.

BANANA FAMILY (ZINGIBREACEÆ)

This very important family includes a number of interesting families of which the banana of commerce (*Musca paradisiaca*) is an example. Another species of the banana (*M. textilis*) produces a fibre from which the Manila hemp is manufactured.

The edible bananas are grown from suckers, but the fibre varieties are grown from seeds.

LILY FAMILY (LILIACEÆ)

This very large and interesting family contains many valuable plants. The flowers are perfect, usually terminal and solitary but occasionally in racemes or spikes. The perianth is more or less tubular and six-parted or united into six lobes; six stamens and a three-chambered, many-seeded superior ovary.

Lily, Asparagus, Onion.—This family may be characterized by the many species of lilies which grow wild or are cultivated for ornamental purposes.

Among other important vegetable plants of this family are the asparagus (*Asparagus officinalis*) and the onion (*Allium cepa* and *A. fistulosum*). Among the ornamental plants are the many true lilies, tulips, hyacinths, lilies of the valley, etc.

Some Bad Weeds.—The family includes a large number of uncultivated plants, some of which are troublesome weeds. Among the most important of these weeds are the wild onions, or wild garlic, which frequently becomes established in old pastures and gives a peculiar odor to milk and butter from cows that feed on it. It is very difficult to eradicate, but can be done by shallow plowing just deep enough to expose the bulbs to the sun, followed by the growing of well-cultivated crops.

Propagation.—The asparagus is usually grown from seed, but old crowns are sometimes divided. Onions are grown from seeds, sets and bulbs. The ornamentals are usually grown from bulbs or seeds.

GRASS FAMILY (GRAMINEÆ)

Annuals or perennials, frequently with fibrous or creeping rhizomes and often stoloniferous at the lower nodes. Flowers perfect (occasionally monœcious or diœcious or polygamous) and borne in spikelets which are collected into spikes or panicles. Perianth imperfect (occasionally wanting) membranous or fleshy. Stamens three or six (occasionally four, two or one).

Ovary superior with one chamber and one ovule and surmounted by two (occasionally three) styles. Stems cylindrical (occasionally flattened), tubular (occasionally hollow). Leaves alternate, in two ranks, springing from the nodes, petioles sheathing the stems. This very large family contains our grains and grasses (Fig. 55).

Wheat (*Triticum vulgare* and varieties) is the well-known

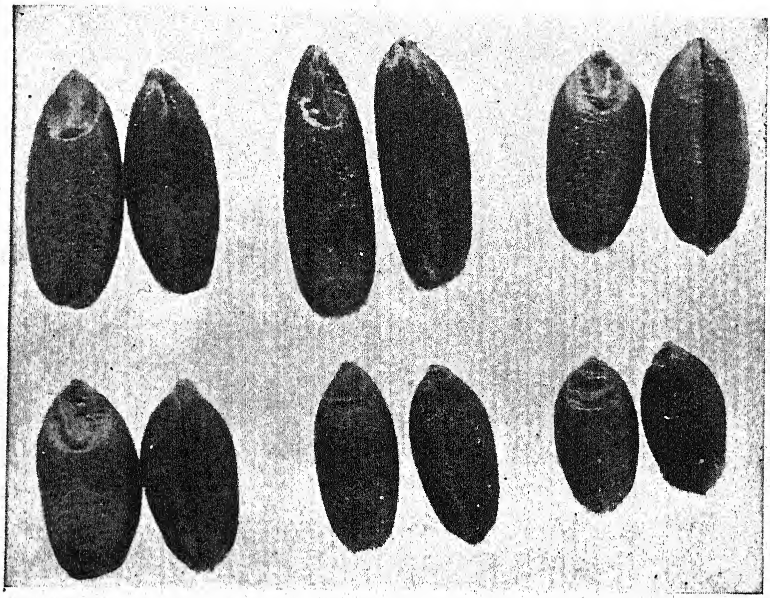


FIG. 150.—Six types of wheat. Top row, durum, Polish wheat, and white winter. Bottom row, red winter, hard winter, and hard spring. ("Productive Farm Crops.")

bread plant of the temperate zones. The spikelets bearing from two to many flowers are arranged in a firm spike. The little flowers are arranged in two rows and protected by glumes which sometimes bear awns or bristles; three stamens and two plum-like stigmas. The fruits (*i. e.*, grain enclosed in ovary coats) are about one-quarter of an inch in length, oval, flattened and grooved on one side. Some varieties are sowed in the early

spring and harvested during the summer and known as "spring wheat." Other varieties are sowed in the fall and harvested the following July and known as "winter wheat." Wheat probably originated in western Asia and was cultivated long before we have any authentic historical records. (Fig. 150.)

Rye (*Secale cereale*) is very similar to wheat and is used as food for both man and beast. We have no satisfactory records telling us where it was first cultivated by mankind. (Fig. 56.)

Barley (*Hordeum vulgare, H. distichum, H. hexastichon* and *H. Zeocriton*) is also similar to wheat and is also used for man and beast. Its cultivation probably antedates historical records.

Oats (*Avena sativa*) have the two- to five-flowered spikelets borne in panicles. The glumes are membranous and without awns; three stamens and two stigmas. Annuals which are sowed in the spring and harvested in July or August. Its geographical range is not so great as most of the other cereals; it grows well in cold regions and rather poorly in warm countries. It probably originated in western Asia and eastern Europe, but we have no very satisfactory records of its early cultivation and uses. Although it is less nutritive than wheat or rye it is very extensively used as food for man and beast.

Millet (*Setaria italica*) is an Asiatic plant cultivated many centuries before the Christian Era. It is very widely but not extensively grown through many temperate and tropical countries. It is very inferior to oats and many other forage crops which can be grown with no greater expense of time and labor.

Rice (*Oryza sativa* and other species) is an important tropical and subtropical plant growing in low, wet lands. We have no definite records telling us when it first became the food of man, but it was cultivated for at least 2800 years before the Christian Era and has probably contributed more food to the human race than any other food plant.

Corn (*Zea Mays*) (Fig. 151) is not typical of the grass family; the stem is solid and the flower is imperfect and monœcious. The staminate flowers are borne in two-flowered spikelets which are in turn borne on the long spikes constituting the tassel; the pistillate flowers are borne on a large spike (cob), each having a long, delicate, thread-like pistil (silk) and the entire ear enclosed in the large bracts (husks). The fruit

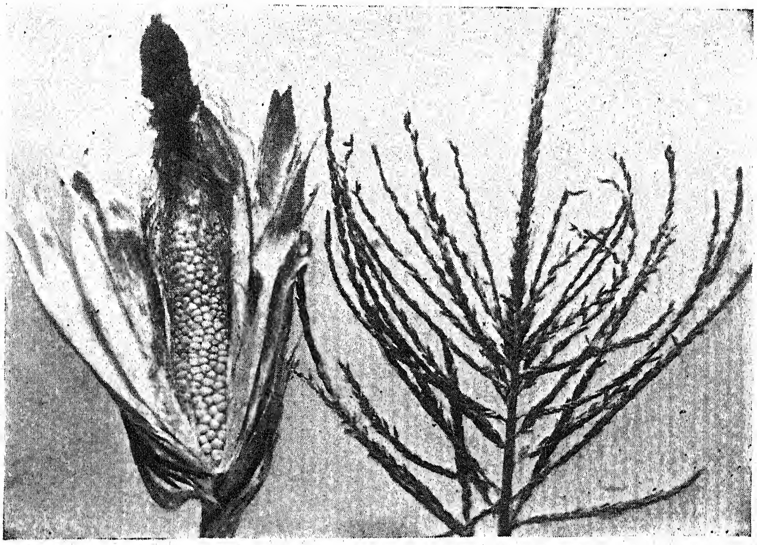


Fig. 151.—Corn showing both pistillate and staminate flowers.

consists of the grain inclosed in the ovary; many of these fruits are arranged in rows on the cob and constitute the ear. This very important plant undoubtedly originated in America and was first introduced into Europe by Columbus in 1520. It is now extensively cultivated in temperate and tropical countries.

There are a great many varieties of corn, but they are usually classified in six groups as follows: (1) the pod corns, in which each grain has a peculiar shuck covering, (2) the pop

corns, (3) the flint corns, (4) the dent corns, (5) the soft corns, and (6) the sugar corns.

Sugar cane (*Saccharum officinarum*) is the well-known tropical and subtropical plant from which the greater part of our sugar of commerce is derived. It is an Asiatic plant, but there are no satisfactory records concerning its early cultivation.

Broom Corn (*Sorghum saccharatum*).—This is an African plant which is grown in the United States for the manufacture of brooms and for stock feed.

QUESTIONS

1. What are the distinguishing characters of the families Cruciferæ, Leguminoseæ, Rosaceæ, Cucurbitaceæ, Convolvulaceæ, Solanaceæ, Juglandaceæ, Cupulifera, Solanaceæ, Liliaceæ and Graminaceæ.

2. (*a*) Make a list of grain-producing plants.
   (*b*) Give the origin of each.
   (*c*) Give the present range of each.
   (*d*) Give the uses of each.
   (*e*) Give the valuation of each.

3. (*a*) Make a list of the fibre-producing plants.
   (*b*) Give the origin of each.
   (*c*) Give the present range of each.
   (*d*) Give the uses of each.
   (*e*) Give the valuation of each.

4. (*a*) Make a list of the fruit-producing plants.
   (*b*) Give the origin of each.
   (*c*) Give the present range of each.
   (*d*) Give the uses of each.
   (*e*) Give the valuation of each.

5. (*a*) Make a list of vegetable plants.
   (*b*) Give the origin of each.
   (*c*) Give the present range of each.
   (*d*) Give the uses of each.
   (*e*) Give the valuation of each.

6. (*a*) Make a list of lumber trees.
   (*b*) Give the origin of each.
   (*c*) Give the present range of each.
   (*d*) Give the uses of each.
   (*e*) Give the valuation of each.

7. Make a list of agricultural plants which are of American origin. Tell something about their present range and uses.

8. Give an example of symbiosis.

9. Tell how legumes improve soils.

10. Describe the propagation of the apple by root grafting.

11. Describe the budding of peaches and plums.

12. How and when are stocks and scions grown, gathered, stored, and used?

13. What are some of the pollination problems with strawberries?

14. Mention the different types of cabbages; of turnips.

15. Describe the peculiar seed-bearing habits of the peanut plant.

CHAPTER XXII

SPECIAL EXERCISES WITH IMPORTANT FAMILIES OF PLANTS

NOTE TO THE TEACHER.—This outline is intended to be very brief and to serve as an outline for further reading in various books which should be in the study-room or laboratory. The exercises are also brief and may be expanded as circumstances may demand. They may be taken in any order to suit the convenience of the teacher. Other exercises may be added to the list or substituted.

1. **The Lily and Its Relatives.**—Dissect and study the flower of the lily. Make a series of drawings to show the shapes of the parts and relations one to another.

Study flower of amarillis, iris, onion and other similar plants and compare with the lily.

2. **Mustard or Radish.**—Select a mustard, radish or any other cruciferous plant in full bloom. Note the differences in the leaves, in the different parts of the plant from base to tips. Make drawings of a few typical specimens.

Dissect the flower, make drawings of the different parts and a diagram showing the number and arrangement of the parts. The character of the ovary can be best studied from seed pods near maturity.

Examine the seeds and make drawings.

Examine the roots and make drawings. Compare with the roots of other cruciferous plants.

How long from seed planting to maturity of a new crop of seeds? Is this the same for all crucifers?

Make a list of food plants belonging to this family. Make a list of native weeds, belonging to this family.

3. **Maple.**—The flowers of the maple open very early; some

of them are in bloom long before the snow and ice have disappeared.

Study the flowers carefully, using a small hand lens. Make drawings and diagrams showing the shape and arrangement of parts.

Examine flowers from different trees. Do they all show both stamens and pistils? Make a record of the date of the blooming and of the appearance of the leaves.

Follow the development of the seeds throughout the season.

Make drawings and measurements of the leaves and seeds from time to time until maturity.

Make a list of the maples in the vicinity. Make a list of their uses.

4. **Gooseberry or Currant.**—Dissect the flowers of one or both and make drawings to show the shape and arrangement of the parts.

Make drawings of fruits. Tell what parts of the flower go to form the fruit.

5. **Cucurbits.**—Examine the flowers of cucumber, melon or pumpkins. Make drawings of parts and diagrams to show the arrangements.

What parts go to make up the fruits?

6. **Composite.**—Study one or more composite flowers such as daisy, sunflower, or dandelion. Note the inflorescence or arrangement of the flowers in the head.

Examine flowers from the margin and centre of the head. Make series of drawings and diagrams to show parts and arrangement of the individual flower.

Make list of useful composite plants.

Make list of weeds belonging to Compositæ.

7. **Oak, Hickory or Walnut.**—Collect, examine and make drawings of both staminate and pistillate flowers.

Compare with willow.

8. **Willow.**—Collect, examine and make drawings of both staminate and pistillate flowers. Compare with oak or hickory or walnut.

9. **Corn Kernel.**—Select good grains of several different kinds of corn, such as flint, soft, pop, and sweet corn.

Make drawings and write descriptions of each. (Fig. 1.)

Soak the grains in hot water for 15 minutes. Cut each grain longitudinally and note the following: hull, endosperm (hard and soft starch), germ (scutellum, plumule, radicle) tip cap. (Figs. 1 and 4.)

Compare, make drawings and write descriptions of each.

Cut another lot of grains in cross section; make drawings and write descriptions.

Write a brief discussion of the uses and value of each of the varieties used.

10. **Corn Seedling.**—Germinate a few grains of corn between layers of wet filter paper.

Examine newly germinated seed and others that have been germinated for several days. Note the plumule, radicle, primary and secondary roots and root-hairs. Make drawings and write descriptions. (Fig. 4.)

Carefully lift seedlings that have been growing in fine, moist soil. Why does the soil cling to the roots? Wash gently and examine the root system.

What does the plant obtain from the soil?

11. **Large Corn Plant.**—Examine a full-sized corn plant. Note the nodes and internodes. How many rows of leaves? Where are they attached?

Note the sheath and blade of the leaf. Is the leaf parallel-veined or net-veined?

Note the brace roots near the base of the plant.

Where is the ear borne?

What part is borne at the top of the plant?

Cut the stalk; examine and describe its structure.

12. **Corn Flowers.**—Where are the corn flowers located? Make a drawing of the tassel. Make a drawing showing one pair of spikelets in place. Separate the parts of a pair of spikelets. Make drawings of parts and drawing to show their position.

Make a drawing of a young ear in silk. The husks are bracts. Remove the husks from one side. Make drawing and show the relation of the silk to the grains.

Each grain is a single flower. What do the grains and silks correspond to in other flowers?

Explain pollination in the corn flower.

13. **Wheat Kernel and Its Germination.**—Examine a grain of wheat and compare it with a grain of corn.

Make germination studies the same as in corn.

14. **Wheat Plant and Flower.**—Compare a stalk of wheat with a stalk of corn.

Where are the flowers located? Make a drawing of a head of wheat. Remove a number of spikelets and make a drawing to show their attachment. Dissect a spikelet and show the following parts: Glumes, palea, stamens, ovary and stigmas. Make drawings of each part and drawing to show their relation to each other.

15. **Oats.**—Repeat the preceding exercise, using oats instead of wheat.

16. **Bean or Pea.**—Make a drawing of the leaf and label all parts. If the plant is a climber explain method of climbing.

Dissect the flower. How many sepals? Make drawings. (Fig. 47.)[1]

Note that there is one large petal or standard, two smaller petals or laterals and two others which form the keel. Make drawings of each and diagram to show the arrangement.

How many stamens and what is their arrangement? Make drawing.

How many pistils? Make drawing and show the parts. What is its relation to the stamens?

Make drawing of pod, showing both outside and inside. (Fig. 47.)

17. **Bean and Pea.**—Examine as many other beans and peas as circumstances will permit. Compare the leaves, method of climbing, flowers and seed pods.

18. **Bean and Pea Seedlings.**—Review your studies on the bean.

Plant a number of beans and peas. Note the methods of germination and compare the seedlings from time to time for a period of two or three weeks. Make drawings.

19. **Purity Test for Clover Seeds.**—Collect a number of samples of clover seeds. One ounce of each is sufficient.

Weigh out two or three grains of each very carefully. (Be sure to use an accurate set of balances such as you will find in the physical and chemical laboratories.)

Spread this sample on a sheet of white paper. Examine through a large lens or reading glass and remove (1) weed seeds, (2) grass and other varieties of clover seed, (3) dirt and other inert material. Weigh, and make and fill the following table in your note-book.

Name of Pupil...

No. of sample.................. Kind of Seed...................

Weight of Pure Seed............	Per cent of pure seed ....
Weight of other clover and grass seed	Per cent of other clover and grass seed ....
Weight of weed seeds	Per cent of weed seed ....
Weight of inert material	Per cent of inert material ....
Total weight	

20. **Germination of Commercial Seeds.**—Count 100, 200, 300, 400, or 500 seeds from preceding exercise. Germinate these seeds between sheets of wet blotting paper.

21. **Weed Seeds.**—How many kinds of weed seeds did you find in the sample used in exercise for purity of clover? Do you know all the kinds?

Heat a quantity of soil long enough to kill all seeds in it. If you are in doubt, keep the soil wet, and in a warm place for a week. If any growth appears, heat it a second time. Plant your weed seeds in this soil and see if you can recognize the little plants.

22. **Grasses.**—Repeat the preceding exercise for grasses.

23. **Potato or Tomato.**—Describe the plant. Make a drawing of the leaf. How are the leaves arranged on the stem? Where are the flowers located? Are they single or in groups?

Make drawing or diagram showing location of flowers and character of inflorescence. Dissect a flower and make drawings of parts.

How many sepals? How many petals? How many stamens? How many pistils? Is it gamo- or poly-sepalous? Is it gamo- or poly-petalous?

24. **Tomato Fruit.**—Examine a few good tomato fruits. Can you find the calyx?

Can you find the corolla?

From what part of the flower is the fruit developed?

Do potatoes form the corresponding part of the flower? Why?

How many seeds in a single tomato?

25. **Potato Tuber.**—Examine a potato tuber. Is the tuber a root or a stem?

What are the eyes of the potato tuber?

Cut a potato tuber so that some of the pieces will have eyes and others not. Plant and watch for germination. Will they all grow? From what part of the piece do the sprouts arise?

26. **Pepper and egg-plants** may be studied in the same manner as indicated in the exercise with tomato fruit.

27. **Apple, Pear or Quince.**—Examine an apple or pear blossom. How many sepals? How many petals? How many stamens? How many pistils? Is it gamo- or poly-sepalous? Is it gamo- or poly-petalous? How are the parts attached? What is the position of the ovary?

28. **Peach, Plum or Cherry.**—Use the same outline as in the preceding exercise.

29. **Apple, Pear or Quince Fruits.**—From what parts of the flower is the apple, pear or quince developed?

Make a drawing of the fruit.

Cut a fruit lengthwise, make drawing and label all parts.

Cut a fruit in cross section, make drawing and label all parts.

30. **Peach, Plum or Cherry Fruits.**—Use same outline as in the preceding exercise.

31. **Blackberry or Raspberry.**—Compare the blossom of a blackberry or raspberry with the blossom of the apple or peach. How does it resemble and how does it differ from the blossom of the apple or peach?

Make a series of drawings showing characters of the flowers.

Examine a berry. From what part or parts of the flower is the fruit developed? Make a series of drawings.

32. **Strawberry.**—Use same outline as in the preceding exercise.

33. **Morning Glory.**—Dissect the flower of the morning glory. How many sepals? How many petals? How many stamens? How many pistils? To what are the various parts attached?

Is the flower gamo- or poly-sepalous? Is the flower gamo- or poly-petalous?

34. **Sweet Potato.**—The sweet potato belongs to the same family as the morning glory and the flowers are almost the same. The sweet potato produces an abundance of blossoms

in the tropical countries, but in the temperate climates it seldom produces blossoms.

Is the edible part a root or a stem? Compare it with the edible part of the white or Irish potato?

35. **Cotton.**—A hollyhock may be substituted in sections where the cotton is not grown. Study the plant. Note its shape, length of internodes, long vegetative and short flower branches of the plant. How many flowers and fruits has it?

Study the flower, and make a series of drawings to show parts.

Make a study of the boll of the cotton or seed-pod of the hollyhock.

APPENDIX

REFERENCES

Atkinson, G. F.: (1) Elementary Botany. New York: Henry Holt & Co., 1898, $1.25.

(2) Lessons in Botany. New York: Henry Holt & Co., 1900, $1.12.

(3) Mushrooms, Edible, Poisonous, etc. New York: Henry Holt & Co., 1903, $3.00.

(4) First Studies of Plant Life. Boston: Ginn & Co., 1901, $1.00.

(5) A College Text Book of Botany. New York: Henry Holt & Co., 1905, $2.00.

Bailey, L. H.: (1) The Survival of the Unlike. New York: The Macmillan Co., 1896 and later, $2.00.

(2) Lessons with Plants. New York: The Macmillan Co., 1898, $1.10.

(3) Plant Breeding. New York: The Macmillan Co., 1895 and later, $1.25.

(4) Botany, an Elementary Text for Schools. New York: The Macmillan Co., 1900 and later, $1.10.

(5) Beginner's Botany. New York: The Macmillan Co., 1909, 60 cents.

Bailey, L. H. (Editor): (1) Standard Cyclopedia of Horticulture. New York: The Macmillan Co., 6 vols., 1914-1916, and later issues, $30.00.

(2) Cyclopedia of American Agriculture, New York: The Macmillan Co., 4 vols., 1907-1909, $20.00.

Bailey, L. H., and Coleman, W. M.: First Course in Biology. New York: The Macmillan Co., 1908, $1.25.

Bailey, W. W.: Botanizing. Providence: Preston & Rounds Co., 1907, $1.00.

Barnes, C. R.: (1) Plant Life, Considered with Special Reference to Form and Function. New York: Henry Holt & Co., 1898, $1.12.

(2) Outlines of Plant Life, with Special Reference to Form and Function. New York: Henry Holt & Co., 1900, $1.00.

Beal, W. J.: Seed Dispersal. Boston: Ginn & Co., 1898 and later, 60 cents.

Bergen, J. Y.: (1) Elements of Botany. Boston: Ginn & Co., 1896 and later, $1.00. (Also with a brief Flora, $1.30.)

(2) Foundations of Botany. Boston: Ginn & Co., 1896 and later, $1.30. (Also with a brief Flora, $1.50. A handbook for teachers is supplied, 30 cents.)

(3) Essentials of Botany. Boston: Ginn & Co., 1909, $1.20. (Also with a brief Flora, $1.50.)

Bergen, J. Y., and Caldwell, O. W.: Practical Botany. Boston: Ginn & Co.

Bergen, J. Y., and Davis, B. M.: (1) Principles of Botany. Boston: Ginn & Co., 1906, $1.50.

(2) Laboratory and Field Manual of Botany (to accompany the preceding). Boston: Ginn & Co., 1907, 90 cents.

Bessey, C. E.: Botany for High Schools and Colleges. New York: Henry Holt & Co., 1880 and later editions, $2.20.

Britton, N. L.: (1) Manual of the Flora of the Northern States and Canada. New York: Henry Holt & Co., 1901, $2.25.

(2) North American Trees, being Descriptions and Illustrations of the Trees Growing Independently of Cultivation in North America, North of Mexico, and the West Indies. New York: Henry Holt & Co., 1908, $7.00.

Britton, N. L., and Brown, A.: An illustrated Flora of the Northern United States, Canada, etc. New York: Charles Scribner's Sons, 3 vols., 1896-1898, $4.00 a volume.

Caldwell, O. W.: Laboratory Manual of Botany. New York: D. Appleton & Co., 1902, 60 cents.

Campbell, D. H.: (4) A University Text Book of Botany. New York: The Macmillan Co., 1902, $4.00.

Clark, C. H.: A Laboratory Manual of Practical Botany. New York: American Book Company, 1898, 96 cents.

Clute, W. N.: (1) Our Ferns in Their Haunts, a Guide to all the Native Species. New York: F. A. Stokes Co., 1901, $2.00.

(2) The Fern Allies of North America, North of Mexico. New York: F. A. Stokes Co., 1905, $2.00.

Collins, F. S.: Green Algæ of the United States. Tufts College Studies, 1909, $3.50.

Conn, H. W.: Bacteria, Yeasts, and Molds in the Home. Boston: Ginn & Co., 1903, $1.20.

Coulter, J. M.: (1) Manual of the Botany of the Rocky Mountain Region. New York: American Book Co., 1885, $1.62.

(2) Plants, a Text-book of Botany (combining two books, Plant Relations and Plant Structures). New York: D. Appleton & Co., 1900. Suggestions for teachers, two pamphets, one by O. W. Caldwell, are supplied to teachers with this work, $1.80.

Gray, Asa: (2) Field, Forest and Garden Botany. Revised by L. H. Bailey. New York: American Book Co., 1868 and later, $1.44.

(5) Elements of Botany. New York: American Book Co., 1887 and later editions, 94 cents.

(8) Manual of the Botany of the Northern United States. Sixth Edition. New York: American Book Co., 1890, $1.62. Field edition, $2.00. Seventh edition, by Robinson, B. L.

Green, J. R.: (1) An Introduction to Vegetable Physiology. Philadelphia: P. Blakiston's Son & Co., 1900 and later, $3.00.

Hilgard, E. W.: Soils, their Formation, Properties, Composition and Relations to Climate and Plant Growth in the Humid and Arid Regions. New York: The Macmillan Co., 1906, $4.00.

Hough, R. B.: Handbook of the Trees of the Northern States and Canada, East of the Rocky Mountains. Photo-descriptive, Lowville, N. Y.: Published by the Author, 1907, $8.00.

Jackson, B. D.: A Glossary of Botanic Terms with their Derivation and Accent. Philadelphia: J. B. Lippincott & Co., 1900, $2.00.

Kerner von Merilaun, A. Translated by F. W. Oliver: The Natural History of Plants. New York: Henry Holt & Co., 4 vols., 1894-1895, $11.00.

Kraemer, Henry: A Text-book of Botany and Pharmacognosy Intended for the use of students of Pharmacy, as a Reference Book for Pharmacists, and as a Handbook for Food and Drug Analysis. Philadelphia: J. B. Lippincott Co., Third Edition, 1908, $5.00.

Leavitt, R. G.: Outlines of Botany for the High School Laboratory and Classroom (based on Gray's Lessons in Botany). New York: American Book Co., 1901, $1.00.

MacDougal, D. T.: (1) The Nature and Work of Plants. An Introduction to the Study of Botany. New York: The Macmillan Co., 1900, 80 cents.

(2) Practical Text-book of Plant Physiology. New York: Longmans, Green & Co., 1901, $3.00.

(3) Elementary Plant Physiology. New York: Longmans, Green & Co., 1902, $1.20.

Osterhout, W. J. V.: Experiments with Plants. New York: The Macmillan Co., 1905, $1.25.

Penhallow, D. P.: A Manual of the North American Gymnosperms. Boston: Ginn & Co., 1907, $4.50.

Sargent, C. S.: (2) Manual of the Trees of North America (exclusive of Mexico). Boston: Houghton, Mifflin & Co., 1899, 75 cents.

Small, J. K.: Flora of the Southeastern United States. New York: Published by the Author at the New York Botanical Garden, 1903, $3.60.

Stevens, W. C.: (2) Plant Anatomy, from the standpoint of the development and functions of the tissues, and handbook of microtechnic. Philadelphia: P. Blakiston's Son & Co., 1907, $2.00.

Strasburger, E., Noll, F., Schenck, H., and Karsten, G., Translated by W. H. Lang: A Text-book of Botany. New York: The Macmillan Co., 1908, $5.00.

Underwood, L. M.: (1) Our Native Ferns and their Allies. New York: Henry Holt & Co., 1881 and later, $1.00.

(2) Molds, Mildews, and Mushrooms. New York: Henry Holt & Co., 1899, $1.50.

Vines, S. H.: (1) Lectures on the Physiology of Plants. Cambridge: University Press, 1886, $5.00.

(2) Elementary Text-book of Botany. New York: The Macmillan Co., 1898, $2.25.

Waters, C. E.: Ferns. A Manual of the Northeastern States. New York: Henry Holt & Co., 1903, $3.00.

GLOSSARY.

Ac′au-les′cent. Apparently stemless.

Ac-ces′so-ry. Something added. Extra organ or part.

Ad-he′rent. Growing to or attached to.

Ad-he′sion. The union of organs of different kinds, as stamens to petals, etc.

Ad′nate. Growing fast to; united.

Ad′ven-ti′tious. Out of the usual order; accidental.

Ag′gre-gate. Assembled close together.

A-kene′, or **a-ken′ium,** or **a-chene′.** An indehiscent seed vessel or fruit, bearing one seed.

Al′ter-nate. Distributed singly at different heights of the stem; not opposite.

Am′ent. A catkin type of inflorescence.

Am′en-ta′ceous. Catkin-like, or catkin-bearing.

A-nal′y-sis (botanical). The process of classifying and finding the names of plants.

A-nat′ro-pous. Having the ovule inverted at an early period in its development, so that the chalaza is at the apparent apex.

An′dre-œ′cium. The stamens of a flower taken together.

An′e-moph′i-lous. Wind-loving; said of wind-pollinated flowers.

An′gi-o-sperms. Plants whose seeds are borne in a closed vessel.

An′nu-al. Yearly.

An′nu-lar cells. Cells with ring-like markings.

An′ther. The part of the stamen that contains the pollen.

An′ther-id′i-um. The organ in cryptograms corresponding to the anther in flowering plants.

A-pet′al-ous. Without petals.

A′pex. The top or point, especially of a leaf.

Ap′i-cal. Belonging to the apex or point.

Ap-pend′age. Any superinduced part.

A-quat′ic. Living in the water.

Ar′bo-re′tum. A collection of trees.

Ar-bo′re-ous. Tree-like.

Ar′che-go′ni-um. The organ in cryptograms corresponding to the pistil of flowering plants.

As-cend′ing, or **as-cend′ent.** Arising obliquely; assurgent.

As-sim′i-la′tion. The function of producing starch or other plant food.

At′ro-pous, or **at′ro-pal.** Not inverted; orthotropous.

Awn (ôn). The bristle or beard of barley and similar plants.
Ax′il. The angle between the petiole and the branch on the upper side.
Ax′is. The stem or other central line of the plant.

Bac-te′ri-um. The smallest organism known; micro-organisms, destitute of chlorophyll, which multiply with great rapidity and cause putrefaction and disease.
Bast-cells. Long cells of bark.
Beard′ed. Having tufts of long hairs, or awns.
Ber′ry. A fruit with a fleshy pericarp.
Bi′col′or. Two-colored.
Bi-en′ni-al. Of two years' duration, bearing seeds the second year only.
Bi-fo′li-ate. With two leaflets.
Bi-la′bi-ate. Two-lipped.
Bi′lobed. Two-lobed.
Bi-loc′u-lar. Divided into two cells.
Bi-no′mi-al. Having two names.
Blade. The expanded part of the leaf.
Bot′a-ny. The science which treats of plants and plant growth.
Bract. The small leaf or scale from the axil of which a flower or its pedicel proceeds.
Branch. A shoot growing from the stem.
Bry-oph′y-ta. Moss and moss-like plants.
Bud scales. Coverings of a bud.
Bulb. An underground bud.
Bulb-if′er-ous. Bearing or producing bulbs.
Bulb′lets. Little bulbs, borne above ground.

Ca-lyp′tra. The hood of the spore-case of a moss.
Ca′lyx. The outer floral envelope.
Cam′bi-um. An old name for the growing cells between the wood and bark; nascent structure.
Cam′py-lot′ro-pous. Having the ovule curved, with the apex near the hilum.
Cap′il-la-ry, or cap-il-la′ceous. Resembling hair; long and slender; the passage of water through small openings.
Cap′i-tate. Head-shaped; growing in close clusters of heads.
Cap′sule. A dry dehiscent seed vessel with more than one carpel.
Car′pel. A simple pistil.
Car′un-cle. An excrescence near the hilum of some seeds.
Car′y-op′sis. A grain; a thin, dry, one-seeded pericarp.
Cat′kin. An ament.

Cau′dex. The trunk or stem of a plant.

Cau-les′cent. Having a distinct stem.

Cau′li-cle. A little stem, or rudimentary stem of a seedling.

Cau′line. Relating to the stem.

Cell growth. Formation and enlargement of cells.

Cel′lu-lar tis′sue. Tissue formed of cells.

Cel′lu-lose. The substance of which cell walls are formed.

Ce′re-al. Relating to grains, corn, etc.

Cha-la′za. The part of an ovule where the covering and nucellus join.

Chlo′ro-phyll. The green substance of leaves and bark.

Cir′cu-la′tion. A moving around (as of the sap).

Cla′vate. Club-shaped.

Cleis-tog′a-mous. Pollination in closed buds.

Climb′ing. Rising by clinging to other objects for support.

Com-plete′ flow′er. One that has all the organs—calyx, corolla, stamens and pistils.

Com-pound′ flow′er. One composed of a number of separate flowers crowded on the torus.

Com-pound′ leaf. One composed of separate leaflets, or little leaves.

Cone. A strobile, a multiple fruit having the shape of a cone.

Cork′y. Of the texture of cork.

Corm. A sort of bulb or fleshy stem.

Co-rol′la. Inner perianth made up of petals.

Co-ro′na. A crown.

Cor′ti-cal bark. Outer bark.

Cor′ymb. A flat-topped or convex cluster of flowers, each on its own foot-stalk, and arising from different points of a common axis.

Cot′y-le′dons. Lobes or seed leaves, or first leaves of the embryo.

Creep′er. A plant that trails on the ground.

Cre′nate. Bordered with round teeth.

Cross′-pol′li-na′tion. The pollination of a plant by pollen from a different individual.

Cru′ci-form. In the form of a Roman cross.

Cryp′to-ga′mia. Name of the division of plants without flowers.

Culm. The straw of grasses.

Cu′ne-ate, or cu-ne′i-form. Wedge-shaped.

Cu′pule. A little cup, as the cup of the acorn.

Cus′pi-date. Having a sharp, stiff point.

Cu′ti-cle. Outer lamina of wall of epidermis.

Cyme. Flower cluster with the oldest flowers at the top or centre.

De-cid′u-ous, Falling at the end of the season.
De-cum′bent. Reclining with the top ascending.
De-fo′li-a′tion. The casting off of leaves.
De-his′cent. Opening by regular valves.
Del′i-ques′cent. Branching, so that the stem is lost in branches.
Del′toid. Like the Greek letter Δ in form.
Den′droid. Tree-like in form.
Den′tate. Toothed.
De-nud′ed. Become naked.
De-pend′ent. Hanging down.
De-pressed. Flattened from above; low.
De-scend′ing. Tending gradually downward.
Dex′trin. A gummy substance produced by the action of diastase upon starch.
Di′a-del′phous. Having stamens grouped into two sets by united filaments.
Di′ag-no′sis. A brief statement of the distinctive character of a plant or group.
Di-an′drous, With two stamens.
Di′a-stase. A peculiar ferment in malt, altering starch into dextrin.
Di-chla-myd′e-ous. Having both calyx and corolla.
Di-chot′o-mous. Two equal forks.
Di-cot′y-le′don-ous. Having two cotyledons, or seed lobes.
Di-cot′y-le′dons. Plants which have two seed leaves in their embryos.
Dif′fuse. Much divided and spreading.
Dig′i-tate. Having several distinct leaflets palmately arranged, as in the leaf of the horse-chestnut.
Di-mor′phous. Having two forms.
Di-œ′cious. Having staminate and pistillate flowers borne on different plants.
Dru-pa′ceous. Like a drupe.
Drupe. A stone fruit, as the peach and cherry.

El′a-ters. Spiral, elastic threads accompanying certain spores.
El′lip-soi′dal. Shaped like an ellipsoid.
El-lip′tic. Having the form of an ellipse.
Em′bry-o. The young plant in the seed.
Em′bry-o sac. The cell in the ovule in which the embryo is formed.
En-dog′e-nous struc′ture. Structure in which the pith and woody fibre are indiscriminately mingled.
En′do-gens. Plants whose structure is endogenous.
En′do-sperm. The food immediately surrounding the embryo.

En-tire′–mar′gined. Having a continuous edge.
En′to-moph′i-lous (flowers). Frequented and pollinated by insects.
E-phem′er-al. Enduring for one day.
Ep′i-carp. The outer layer of a seed vessel.
Ep′i-der′mis. Outer layer of cells.
Es-sen′tial or′gans (of a flower). Stamens and pistils.
Ex′o-carp. Outer layer of a pericarp.
Ex-og′e-nous struc′ture. Structure like an exogen.

Fas′ci-cle. A bundle, or cluster.
Feath′er–veined. With all veins from the sides of the mid-rib or mid-vein.
Fer′ti-li-za′tion. Union of sex cells.
Fi′bro-vas′cu-lar. Containing woody fibres and ducts.
Fil′a-ment. The stalk of a stamen.
Fil′i-form. Slender, like a thread.
Flesh′y. Composed of firm pulp or flesh.
Flo′ral en′ve-lope. The perianth of a flower.
Flow′er. The organ which produces the seed.
Fo′li-ate. Provided with leaves.
Fol′li-cle. A one-celled, many-seeded carpel, opening by the ventral suture.
Fo-ra′men. A small opening or orifice.
Frond. An organ which is both stalk and leaf; usually applied to ferns.
Fruc′ti-fi-ca′tion. The act of producing fruit.
Fruit. A ripened pistil; a seed vessel with its contents.
Fru-tes′cent. Shrubby in character.
Fu′ni-cle, fu-nic′u-lus. The stalk of an ovule or seed.
Fu′si-form. Spindle-shaped.

Gam′o-pet′a-lous. Having the petals united; sympetalous.
Gam′o-sep′a-lous. With the sepals united.
Gla′brous. Smooth, not hairy.
Glu-ma′ceous. Glume-like; glume bearing.
Glumes. Bracteal coverings of flowers or of the seeds of grains and grasses.
Grain. The gathered seeds of cereal plants.
Gym′no-sper′mæ. A class of exogenous plants characterized by naked seeds.

Has′tate. Triangular, with the base lobes abruptly spreading as in a halberd.
Heart′wood. The wood near the central part of an exogenous tree or shrub.
Her-ba′ceous. Green and cellular in texture.
Her-maph′ro-dite (flower). Having both stamens and pistils.

Het´er-og´a-mous. Having two sorts of flowers on the same head.
Hi′lum. The eye, or scar, of the seed.
Hir′sute. Hairy; with rather long hairs.
His′pid. Bristly; having stiff hairs.
His-tol′o-gy. The science of cells and tissues.
Hy′a-line. Transparent, or nearly so.
Hy′brid. A cross breed between two species.

Im-per′fect flow′er. A flower wanting either stamens or pistils.
In-com-plete′ flow′er. Wanting calyx or corolla.
In-cum′bent. Having the radicle lying against the back of one of the cotyledons.
In-def′i-nite. Too numerous or variable for specific enumeration.
In-def′i-nite in′flo-res′cence, or in′de-ter′mi-nate in′flo-res′cence. A process of inflorescence in which the flowers all arise from axillary buds, the terminal bud continuing to grow, and extending the stem indefinitely.
In′de-his′cent. Not opening.
In-dig′e-nous. Native to a country.
In-du′si-um. The shield of the fruit dots (sori) in many ferns.
In′flo-res′cence. Mode of flowering, or the arrangement of flowers on a plant.
In′nate. Growing on the top of the part that sustains it.
In-sert′ed. Situated upon, growing out of, or attached to some part.
In-teg′u-ment. A coat or covering.
In′ter-cel′lu-lar (passages, spaces). Lying between the cells.
In′ter-node. The space between two nodes.
Ir-reg′u-lar flow′ers. Flowers whose like parts differ either in size or shape.

Key-fruit. A dry, indehiscent, usually one-seeded, winged fruit; a samara.

Lac-tif′er-ous tis′sue. A tissue whose cells and ducts bear milk-like fluid.
Leg′ume. A seed vessel which opens by both a ventral and dorsal opening, as the bean, pea, etc.
Len′ti-cel. A small oval rounded spot upon a stem or branch from which the underlying tissues may protrude.
Loc′u-lar. Relating to the cell or compartment of an ovary.

Med′ul-la-ry rays. Rays of cellular tissue seen in a transverse section of exogenous wood which pass from the pith to the bark.

Mer'is-matic. Dividing into cells or segments by the formation of internal partitions; *i. e.*, the formation of new cells.

Mes'o-carp. The middle layer of a pericarp, consisting of three distinct layers.

Mi'cro-pyle. An opening in the outer coat of a seed through which the pollen tube enters the ovule.

Mid'–rib, or mid'–vein. The central vein of a leaf.

Mon'a-del'phous. Having the stamens united in one body by the filaments.

Mon'o-cot'y-le'don. A plant having only one cotyledon, or seed leaf.

Mo-nœ'cious. Having stamens and pistils on the same plant.

Mon'o-pet'al-ous. Having but one petal.

Mor-phol'o-gy. That branch of biology which deals with the structure of animals and plants, and treats of the forms of organs, describing their homologies.

My-ce'li-um. The white threads of filamentous growth of a fungus.

No'men-cla'ture. The technical names used in any particular branch of science or art.

Nu-cel'lus. The essential body of an ovule where the embryo is developed.

Nu-cle'o-lus. A dense rounded body within a nucleus.

Nu'cle-us. A dense body within the protoplasm of a cell.

Ob-cor'date. Heart shaped, with the attachment at the pointed end.

Ob-lan'ce-o-late. Lanceolate, narrowing toward the point of attachment.

Or'gan. Any member of a plant, as a leaf, a stamen, etc.

O'vule. The young seed.

Pa'lea. Chaff, or chaff-like bract.

Pal'et. Same as palea.

Pal'mate. Lobed so that the sinuses point to the apex.

Pan'i-cle. A branching raceme.

Pa-pil'i-o-na'ceous. Resembling the butterfly, as in some of the legumes.

Pap'pus. The awns, or bristles, which represent the calyx in compositæ.

Par'al-lel–vein'ed. Having the veins or nerves extending from the base of the leaf to the apex, parallel to the midvein.

Pa-raph'y-sis. A minute-jointed filament among the archegonia and antheridia of mosses.

Par'a-site. A plant obtaining nourishment immediately from another plant to which it attaches itself.

Pa-ren'chy-ma. Soft cellular plant tissue, like the pulp of leaves, having no wood fibre.

Pa-ri'e-tal. Attached to the main wall of the ovary.

Per-en′ni-al. Living several years.

Per′fect flow′er. A flower having both stamens and pistils.

Per′i-anth. Calyx or corolla, or both; the leafy parts of a flower surrounding the stamens and pistils.

Per′i-carp. The ripened ovary; the covering of the seed.

Pet′al. Part of the corolla.

Pet′i-ole. The stalk of a leaf connecting the leaf with the stem.

Phæ′no-ga′mia, or **pha-ne-ro-ga′mi-a.** Name of that division of the vegetable kingdom which bears visible flowers.

Pis′til. Organ of a flower, made up of ovary, style and stigma, or ovary and stigma.

Pith. The soft tissue in the centre of the stems of dicotyledonous plants.

Pla-cen′ta. The part of a pistil or fruit to which the ovules, or seeds, are attached.

Plu′mule. The first bud of the embryo plant.

Pod. A capsule, especially a legume.

Pol′len. The fructifying cells borne in the anthers.

Pol′len tube. The slender tube sent down from the pollen through the style of the pistil to the ovum in the ovule.

Pol′li-na′tion. The act of transferring pollen to the stigma.

Pol′y-cot′y-le′don-ous. Having many (more than two) cotyledons, as in the pines.

Pol′y-pet′a-lous. Having the petals separate from each other.

Pol′y-sep′a-lous. Having the sepals separate from each other.

Pome. A fruit like an apple.

Pro-cum′bent. Trailing, prostrate.

Pro-thal′li-um, pro-thal′lus. The minute primary growth from the spore of ferns which bears the true sexual organs.

Pro′to-plasm. The primary organic substance of the cell.

Pseu′do. False.

Pter′i-do-phytes′. Ferns and fern-like plants.

Pu-bes′cent. Covered with fine short hairs.

Ra-ceme′. A flower cluster with an elongated axis and many one-flowered lateral pedicels.

Ra′chis, or **rha′chis.** The principal axis in a spike, raceme, panicle or corymb.

Rad′i-cle. The rudimentary stem of a plant which supports the cotyledons in the seed, and from which the root is developed downward; a rootlet.

Ra′phe. The continuation of the seed stalk along the side of an anatropous ovule or seed, forming a ridge or seam.

Re-cep′ta-cle. The apex of the flower stalk, from which the organs of the flower grow.

Reg′u-lar. Having all the parts of the same kind alike in size and shape.

Res′pi-ra′tion. Breathing; the absorption by plants of oxygen; the oxidation of assimilated products, and the release of carbon dioxide and watery vapor.

Rha′chis. The axis of a spike inflorescence.

Rha′phe. The continuation of the seed stalk along the side of an anatropous ovule or seed, forming a ridge or seam.

Rhi′zome. An underground stem.

Root. The descending axis of a plant; the part of a plant that grows downward into the ground. It bears no true buds.

Root′ cap. A mass of dead cells which cover and protect the growing cells at the end of a root.

Root′ stock. Same as rhizome.

Sag′it-tate. Arrow shaped.

Sam′a-ra. Indehiscent, winged fruit.

Sap. The watery fluid taken up by the root, and moved through the vessel up to the leaves.

Sap′ wood. The last growth of wood in an exogen.

Seed. Matured ovule.

Se′pal. One of the parts of the calyx.

Ses′sile. Without stem.

Sol′i-ta-ry. Growing alone or singly.

So′rus. A fruit dot of ferns.

Spa′dix. A spike with a fleshy axis.

Spathe. A large bract, or a pair of bracts, inclosing a flower cluster.

Spike. An inflorescence in which the flowers are sessile on a lengthened axis.

Spo-ran′gi-um. A spore case in cryptogamous plants.

Spore. A reproductive grain in flowerless plants, analogous to a seed in flowering plants.

Sta′mens. The organs that produce pollen, consisting of filament and anther.

Sto′lon. A branch at the base of a plant which roots easily.

Sto′ma. One of the openings in the epidermis of a leaf; a breathing pore.

Style. That part of the pistil between the ovary and the stigma.

Su-pe′ri-or. Above the ovary.

Su-pe′ri-or o′va-ry. Ovary free from calyx.

Sym-pet′al-ous. Having the petals united; gamopetalous.

Thal′lus. A mass of cellular tissue, usually in the form of a flat stratum or expansion, instead of stem and leaves.

Tri′chome. A hair on the surface of a leaf or stem, or any modification of a hair.

Tu′ber. A fleshy underground stem, or branch, with buds.

Um′bel. An inflorescence in which the pedicels all spring from the same point, like the ribs of an umbrella.

Veins. The system of branching vascular woody tissue seen in leaves.

Xy′lem. That portion of a fibro-vascular bundle developed into wood cells.

Zo′ö-spore. A spore provided with one or more slender cilia, by the vibration of which it swims in the water.

INDEX